Insights into language processing in aphasia from semantic priming and semantic judgement tasks

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Abstract

The nature of semantic impairment in people with aphasia (PWA) provides the background to the current study, which examines whether different methods of semantic assessment can account for such deficits. Cognitive ability, which has previously been linked to language ability in PWA, may impact on test performance and was therefore also examined. The aims of the current study were to compare performance of control participants and PWA on implicit and explicit assessment of semantics, and to relate it to performance on tests of cognition. The impact of semantically similar versus associative relationship types between test stimuli was also considered. Three experimental semantic tasks were developed, including one implicit measure of semantic processing (Semantic Priming) and two explicit measures (Word to Picture Verification and Word to Picture Matching). Test stimuli were matched in terms of key psycholinguistic variables of frequency, imageability and length, and other factors including visual similarity, semantic similarity, and association. Performance of 40 control participants and 20 PWA was investigated within and between participant groups. The relationship between semantic task performance and existing semantic and cognitive assessments was also explored in PWA. An important finding related to a subgroup of PWA who were impaired on the explicit experimental semantic tasks but demonstrated intact semantic processing via the implicit method. Within tasks some differences were found in the effects of semantically related or associated stimuli. No relationships were found between experimental semantic task performance and cognitive task accuracy. The research offers insights into the role of implicit language testing, the impact of stimuli relationship type, and the complex relationship between semantic processing and cognition. The findings underline the need for valid and accurate measures of semantic processing to be in place to enable accurate diagnosis for PWA, in order to direct appropriate intervention choice and facilitate successful rehabilitation.

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Table of contents

List of tables

List of figures

List of abbreviations

ATL….Anterior temporal lobe

BNC…British National Corpus

CAT….Comprehension Aphasia Test

CCT….Camel and Cactus Test

CLQT….The Cognitive Linguistic Quick Test

CSB….Cambridge Semantic Battery

CSC….Controlled semantic cognition

fMRI….Functional magnetic resonance imaging

ISI…Inter-stimulus interval

ms….Milliseconds

PALPA….Psycholinguistic Assessments of Language Processing in Aphasia

PIL….Phonological input lexicon

PPT….Pyramids and Palm Trees

PWA….People with aphasia

RP….Relatedness proportion

SOA…Stimulus onset asynchrony

SD…Semantic dementia

SLT….Speech and language therapy

SST….Semantic similarity rating task

SP….Semantic priming

STM….Short term memory

TEA….The Test of Everyday Attention

VOSP….Visual Object and Space Perception Battery

VST….Visual similarity rating task

WPM….Word to picture matching

WPV….Word to picture verification

Chapter 1 Semantics and aphasia

1.1 Introduction

In the latter half of the nineteenth century the study of semantics in aphasia commenced with Karl Wernicke's identification of patients with temporal lobe lesions and associated lexical comprehension disorders (Kolb & Whishaw, 2003). As the twentieth century progressed there began a shift away from differentiating aphasia subtypes based on lesion loci, towards a psycholinguistic focus on language comprehension and production. In his work in 1920, Henry Head described subtypes of aphasia, including one classification based on semantic level impairment:

> One other form of disorder emerges from analysis of the clinical phenomena due to unilateral lesions of the brain. This may be called "semantic," because it is comprehension of the significance of words and phrases, as a whole, which is primarily affected. (pp.142)
>
> These semantic disorders interfere seriously with the actions of daily life and render the patient useless for any but the simplest employment; and yet his memory and intelligence may remain on a comparatively high general level. (pp.157)

Historically, much focus was placed on the production deficits associated with aphasia, however over the last century consideration regarding deficits in comprehension and the concomitant psychosocial impact of aphasia has developed significantly (Tesak & Code, 2008). We now understand that a lexical semantic impairment can result in errors in both language production and comprehension, and we have a far greater awareness of the potential effect on people's daily lives. Although the primary focus of this thesis is not quality of life in people with aphasia (PWA), it remains the foundation and ultimate goal of the research to improve individuals' rehabilitation opportunities and mitigate the long-term negative psychosocial impact of aphasia. The contents of the thesis will discuss different assessment methods of single word comprehension in PWA, in the context of seeking refined diagnosis and subsequent choice of intervention approach. This in turn will hopefully contribute to improved speech and language therapy rehabilitation for PWA, and, as a result, improved quality of life. In addition, the content contributes to furthering theoretical knowledge regarding lexical semantic processing, the factors influencing assessment of lexical semantics in PWA, and the role of other cognitive functions and executive function in performance on semantic assessment.

This opening chapter will discuss semantic memory and lexical semantics in relation to aphasia, introduce storage versus access accounts of disorders, and other accounts of comprehension impairment in aphasia, and evaluate current methods of lexical semantic assessment used clinically and in research with PWA.

1.2 Semantic memory

Tulving (1972) importantly drew the distinction between two memory systems: semantic memory and episodic memory. Semantic memory consists of all our general knowledge or facts, such as information about people, object and event names and attributes, opinions, beliefs, categories and concept associations, for example, that squirrels have tails, like nuts and live in woodland areas. However, this is without specific knowledge of when we acquired the information (Binder & Desai, 2011). Episodic memory consists of knowledge of experienced events in specific contexts, for example a specific picnic you went on last summer where a squirrel stole your sandwich. Episodic memory relies on the multisensory knowledge about objects, words, and sounds stored in semantic memory, to allow people to remember, consider and imagine things that are not available to the senses in the present moment (Tulving, 2002), serving as storage for personally relevant experiences (Tulving, 1993).

1.3 Models of semantic memory

The nature of the semantic system is represented differently in several models of language processing, and is often discussed in relation to localist or distributed network models (Hutchinson, 2003). Network models propose a distinction between representations of lexical and semantic memory networks that are separate but connected i.e. phonological and orthographic word forms are stored separately but linked to word meaning (Collins & Loftus, 1975; McNamara, 1992; Seidenberg & McClelland, 1989). In localist network models of semantic memory it is proposed that conceptual knowledge is stored in holistic units, called nodes, which are connected to one another and each node represents a specific concept (Collins & Quillian, 1969). Each node is stored with a group of properties in a hierarchical way (Funnell, 2000), for example the node for ‘bird’ would specify ‘has wings’, ‘has feathers’, ‘can fly’, ‘sings’, which would be linked to other nodes for specific birds e.g. flamingo, ‘is pink’. The original network models were subsequently developed to describe node organisation based on semantic similarity and spreading activation, whereby the activation spreads throughout the network once a concept is activated, and the more properties concepts share, the more links that are present, and the stronger the connection (Collins & Loftus, 1975; as illustrated in Figure 1.1). In feature models of semantic memory, concepts are represented by sets of features. To reveal relationships between concepts, such as category membership, the sets of features are compared, rather than connections representing the relationships (Smith, Shoben, & Rips, 1974). It has been argued however, that network models are reductive in that they fail to capture dynamic aspects of word meaning that will differ between people based on individual variation in world experiences, memory, perception and imagination (Johnson-Laird, Herrmann & Chaffin, 1984).

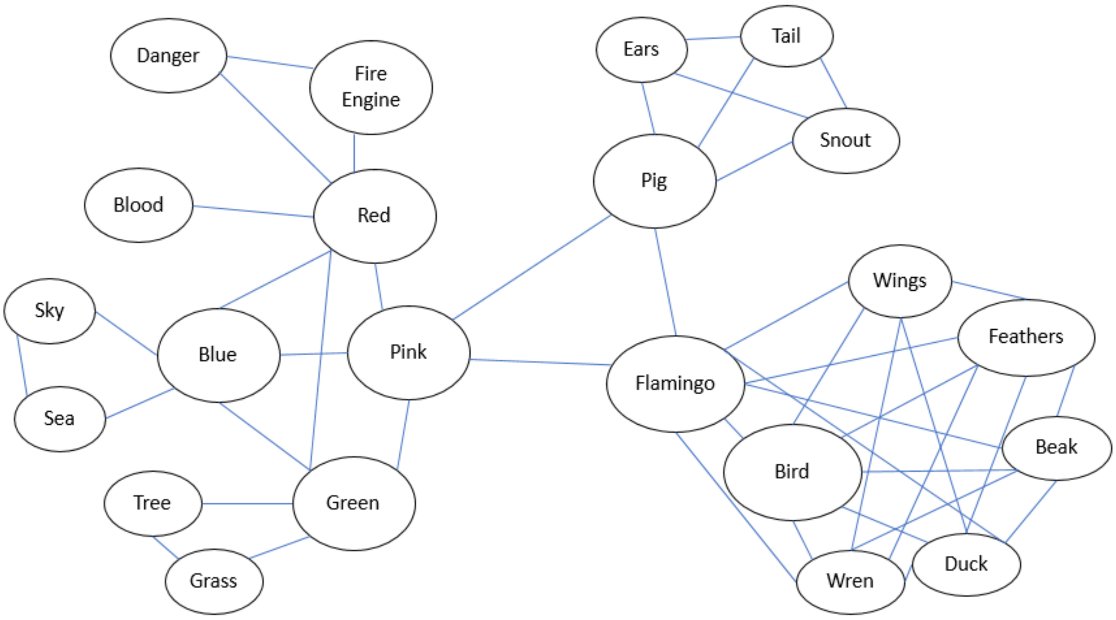

Figure 1.1: Example of a semantic network with concepts represented by nodes

Distributed connectionist network models have been proposed in which concepts are represented as patterns of activation across a network of interconnected units, and similar concepts share similar patterns of activation (Borowsky & Masson, 1996; Joordens & Becker, 1997; Masson, 1995; McRae, de Sa, & Seidenberg, 1997; Moss, Hare, Day, & Tyler, 1994; Plaut, 1995; Sharkey & Sharkey, 1992). Within a distributed network, units are conceived as representing a semantic feature that may be related to many different concepts (Smith & Medin, 1981), however they do not necessarily resemble verbalisable whole word features as such (e.g. ‘has fur’) (Plaut, 1995). Units are typically modularised, for example into visual and verbal modules of information, or input and output, which may or may not be connected (Farah & McClelland, 1991). A pattern of activation occurs as a response to a stimulus, such as seeing a word, and is established by the weights of connections (McNamara, 2005). When a person learns the meaning of a word the weights of connections between sets of units alter, until a particular pattern of weighting (e.g. barks, has fur, chases cats, loyal) represents a specific concept (dog). Related concepts will have similar patterns of activation (Hutchison, 2003). As semantic knowledge in the network is distributed across many connection weights, even when parts of the system are damaged, some semantic processing can still occur; this allows for the graceful degradation in semantics seen in neuropsychological case data (McNamara, 2005). This is in contrast to localist the semantic network models which implies that after damage some concepts can be obliterated while others remain intact.

Testing between the models is challenging as the idea of conceptual features or properties are central to both. A distinction between the flow of information in localist versus distributed models can be drawn, in that localist models often describe an automatic spread of activation between semantically related and associated nodes within the network (Collins & Loftus, 1975; Neely, 1977; Posner & Synder, 1975) i.e. dog will activate concepts such as *bark*, *cat*, *lead, bone.* In contrast, associated concepts will become activated in distributed models due to the similar patterns in activation (Hutchinson, 2003).

1.3.1 Semantic representations

Within the semantic memory literature there has been further debate concerning the representation of semantic memory as modality specific or amodal. For example, accounts of modality-specific semantic memory propose that perceptual and lexical semantic information are stored separately. The perceptual system’s role in recognising stimuli is followed by a separate activation of other semantic features in a distinct conceptual representation within a semantic memory system (Shallice, 1988), however evidence in support for this is limited (Riddoch, Humphreys, Coltheart, & Funnell, 1988). Amodal semantic memory systems have since been described that propose a single integrated amodal store of conceptual information within which conceptual and perceptual information is incorporated (Rogers, Hodges, Lambon Ralph, & Patterson, 2003). Recent depictions of the amodal model of semantic memory are presented as a hub and spoke architecture in which multimodal verbal and nonverbal representations are stored in distributed modality-specific cortices (the spokes), mediated by a transmodal region (the hub), which is represented bilaterally in the anterior temporal lobes (ATL) (Patterson, Nestor & Rogers, 2007). Lambon Ralph, Jefferies, Patterson, and Rogers (2017) have provided a recent review of the theory, describing a two system controlled semantic cognition (CSC) framework for semantic memory: the first system relates to the distributed conceptual representations and ATL hub, while the second system refers to the executive control which flexibly manipulates the semantic knowledge in a task, time or context-oriented way.

Evidence for the distinction between semantic representations (stored knowledge) and semantic control (a form of access disorder) has been illustrated from the study of semantic dementia and semantic aphasia. Semantic dementia (SD) is a progressive neurological condition in which individuals present with generalised impairment of semantic memory yet preservation of other language and cognitive domains including syntax, phonology, visual-perceptual skills and episodic memory (Hodges, Patterson, Oxbury, & Funnell, 1992; Snowden, Goulding, & Neary, 1989). As the condition progresses, people experience increased difficulty in comprehending meaning from words and the senses, including environmental sounds, touch and smell (Bozeat, Lambon Ralph, Patterson, Garrard, & Hodges, 2000) therefore demonstrating impairment in both lexical and non-verbal semantics. Output tasks are also impaired, including errors in picture naming (Lambon Ralph, Graham, Ellis & Hodges, 1998), reduced feature specificity in drawing objects (Bozeat et al., 2003) and reduced amount of detail when verbally defining objects or object names (Lambon Ralph, Graham, Patterson, & Hodges, 1999). In contrast, semantic aphasia (SA) is used to refer to an acquired language difficulty involving lexical semantic impairment, in which individuals present with a multimodal semantic deficit due to difficulty accessing and applying their knowledge flexibly (Jefferies, Baker, Doran, & Lambon Ralph, 2007; Jefferies & Lambon Ralph, 2006). Individuals with SA and SD all present with lexical comprehension difficulties affecting both receptive and expressive abilities, however different causes of this impairment have been proposed and related to the differential loci of neurological damage. In SD semantic knowledge is believed to degrade (Hodges et al., 1992; Mummery, Patterson, Price, Ashburner, Frackowiak, & Hodges, 2000; Patterson, Nestor, & Rogers, 2007) whereas in SA difficulties are believed to arise from difficulty accessing semantic information (e.g. Warrington & Chipolotti, 1996) or from impairment in semantic control (Jefferies at al., 2007; Corbett, Jefferies, Ehsan & Lambon Ralph, 2009; Noonan et al., 2010). Differences in impairment of neuroanatomy in people with SA and SD, that highlight the distinction between impairments of semantic storage versus access, are summarised below.

1.3.2 Neuroanatomy of the semantic system

The discussion concerning access, storage and executive control of semantic information has been supported by debate regarding the specific brain regions responsible for semantic processing (e.g. Anzellotti, Mahon, Schwarzbach, & Caramazza, 2011; Hickok & Poeppel, 2007; Martin, 2007; Patterson, Nestor & Rogers, 2007; Wise, 2003). A range of neuropsychological and neuroimaging data has contributed to the proposal of a complex map of critical brain regions involved in semantic processing, including the anterior temporal lobes bilaterally and a left-lateralised network distributed through regions of the temporal and inferior parietal lobes (Binder & Desai, 2011), including the posterior middle temporal gyrus (pMTG), left inferior frontal gyrus (LIFG), and inferior parietal cortices (Jefferies, 2013).

The observed severity of the semantic impairment in SD has been associated with the extent of hypo-metabolism and bilateral atrophy of the anterior temporal lobes (ATL) (Mummery et al., 2000; Nestor, Fryer, & Hodges, 2006). For example, it has been shown that when repetitive transcranial magnetic stimulation is applied to the left or right temporal poles, processing is slowed in synonym judgement tasks, requiring semantic knowledge, but not in equally challenging non-semantic number judgement tasks (Lambon Ralph, Pobric, & Jefferies, 2009).

Language difficulties observed in post-stroke aphasia are associated with different neurological damage than in individuals with SD. Due to the neuroanatomy of the vascular system, neurological damage caused by stroke rarely produces focal lesions in the ATL (Phan, Donnan, Wright, & Reutens, 2005) and semantic processing impairment is related to unilateral left hemisphere damage to language regions in the temporo-parietal and/or frontal areas (Berthier, 2001; Chertkow, Bub, Deaudon, & Whitehead, 1997; Jefferies, 2013; Lambon Ralph, 2014). Experiments with neurologically intact participants demonstrated that the left inferior prefrontal cortex becomes activated on tests with high semantic control demands (Demb et al., 1995; Gold & Buckner, 2002; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997; Wagner, Paré-Blagoev, Clark, & Poldrack, 2001), these areas can be damaged in PWA with frontal infarcts. In the Jefferies and Lambon Ralph study (2006) comparing patients with SD and SA, some SA patients presented with either frontal or temporo-parietal lesions, leading the authors to discuss the links between the two networks and the integrated roles that they may play in semantic control.

Functional neuroimaging provides further evidence that left temporo-parietal and inferior prefrontal areas are associated with selection and control of cognitive processes (Garavan, Ross, Li, & Stein, 2000; Peers et al., 2005) including semantic cognition (Berthier, 2001; Devlin, Matthews & Rushworth, 2003), which supports the semantic control explanation of semantic impairment in post-stroke aphasia. Overall, the combination of neuropsychological and neuroimaging data suggest that a three-part neural network including the left prefrontal cortex, temporo-parietal and bilateral anterior temporal regions are responsible for flexible semantic cognition (Noonan et al., 2010).

1.3.3 Lexical semantics

In the broadest sense, semantics can be defined as meaning. In considering a linguistic interpretation, semantics refers to the study of meaning communicated via language at a word and sentence level, with the consideration of the context in which they occur (Saeed, 1997). For example, a word or sentence will have a literal meaning, independent from a speaker meaning, which may vary according to the speaker's intent; "it's really hot in here" could be a statement about the room temperature or alternatively an indirect request for the listener to take some action to cool the room down, such as opening a window. The understanding and interpretation of semantics taken here is derived from models of language processing developed from psycholinguistics and cognitive neuropsychology, which owe more to theories of semantic representation and semantic memory from psychology than linguistics.

The study of semantics has been integral to the consideration of language breakdown in aphasia, as communicative intent is fundamentally grounded in the desire to convey meaning, and breakdown in the semantic system disrupts this ability to comprehend or express meaning (Shelley-Tremblay, 2011). Comprehension and production of words requires access to stored knowledge of objects, concepts and words (Nickels, 1997). Often the term lexical semantics is used to refer to a linguistic level of semantic knowledge, with 'concepts' used to refer to a pre-lexical or non-verbal level. The separateness of lexical semantic and non-verbal semantics is debated however, and the terms are often used interchangeably (Nickels, 2001). In the aphasia literature the term 'semantics' is used to refer to the meanings of words, often without distinction of the separate verbal and non-verbal levels, with the internal representations referred to as semantic representations (Ellis & Young, 1996). From this point on the 'semantic system' will be used to refer to the lexical semantic system, as incorporated into models of language processing.

1.4 Semantic impairment in aphasia

People with post-stroke aphasia can experience impairment of semantic knowledge and/or processing which can affect comprehension and production of language, resulting in a wide range of deficits leading to varying levels of receptive and expressive language difficulties. There are a range of behaviours/markers that may suggest that an individual has a semantic processing impairment. In tests of single word comprehension, such as spoken or written word to picture matching, people with aphasia (PWA) may choose semantic distractors rather than the target stimuli (see patient KE: Hillis, Rapp, Romani, & Caramazza, 1990; and patient JCU: Howard & Orchard-Lisle, 1984). Overt lexical semantic selection errors that are related in meaning to the target, for example producing the word *tiger* for *lion*, or *month* for *week*, can also signal a semantic processing difficulty (Nickels, 1997). This has been demonstrated in output tasks including word repetition, spoken or written naming, (see patients RGB and HW: Caramazza & Hillis, 1990; patient EA: Shelton & Weinrich, 1997) or reading aloud (see patients GR and KU: Marshall & Newcombe, 1973). Particular patterns of impairment in aphasia will be discussed in more depth in section 1.4.2.

In considering the different ways in which language processing can break down in aphasia, it is useful to refer to cognitive neuropsychological models of language processing. The Patterson and Shewell (1987) model has been paramount in informing aphasia assessment and therapy, and will be outlined below.

1.4.1 Models of single word processing

Theories of language processing and models of its functional architecture have been founded from evidence of non-brain damaged speakers (Butterworth, 1992; Dell, 1986; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Levelt, 1992; Levelt, Roelofs, & Meyer, 1999; Nickels, 1997; Plaut, 1996, 1997; Rapp & Goldrick, 2000) and case studies of adults with acquired impairments (Dell, et al., 1997; Tikkala & Uhola, 1996). Cognitive neuropsychological models of single word comprehension and production illustrate the different levels of breakdown that can occur within the language processing system (e.g. Patterson & Shewell, 1987; Caramazza, 1997; Dell, Chang, & Griffin, 1999). Often referred to as the ‘box and arrow approach’, distinct cognitive components are represented as boxes, levels or modules, with interconnections and flow of information between the different levels of information processing represented as arrows, relating to the temporal processing of lexical items - see Figure 1.2 (adapted from Whitworth, Webster and Howard, 2014). In theory, any of the boxes or connections within the model can be impaired due to brain lesions, reflecting different patterns of language disorder observed in aphasia.

Cognitive neuropsychological models designed to understand cognitive functions follow a set of core assumptions, including: i) functional modularity, that specific cognitive systems or modules independently represent a specific form of processing, and thus can be independently impaired (Ellis & Young, 1996); ii) anatomical modularity, that functional modularity represents some degree of anatomical modularity – localised and disperse brain areas may be involved in the cognitive processes associated with one module (Coltheart, 2001) therefore selective impairments can result from brain damage to areas associated with particular modules or their connections (Whitworth et al., 2014); iii) uniformity, that individuals share similar functional architectures for the same cognitive areas (Coltheart, 2001); and iv) subtractivity, that patterns of behaviour following brain injury can be elucidated via comparison of an unimpaired, intact cognitive system that has damaged components or connections, i.e. brain damage can subtract from the system but not add to it (Ellis & Young, 1996).

The Patterson and Shewell model (1987; see Figure 1.2) is a representation encompassing many of the conceptualised levels of language processing involved in the models mentioned above. The semantic system is represented as unimodal, a central store of meanings, to and from which all modalities have access, therefore impairment within a central semantic system has implications for all input and output processing routes that involve semantics (Harley, 2001). Although the model provides limited description of the makeup of the semantic system, and other levels of processing represented, it is widely used by clinicians involved in aphasia rehabilitation and has informed The Psycholinguistic Assessments of Language Processing in Aphasia (PALPA), a clinically influential set of language tests (Horton & Byng, 2002). The language tasks are designed to investigate PWA's impaired and intact abilities in spoken and written input and output modalities (Kay, Lesser & Coltheart, 1992). Models of language processing can provide useful frameworks to formally assess and identify areas of breakdown in aphasia, which can subsequently be used to inform therapy (Laine & Martin, 2012; Whitworth, Webster & Howard, 2012).

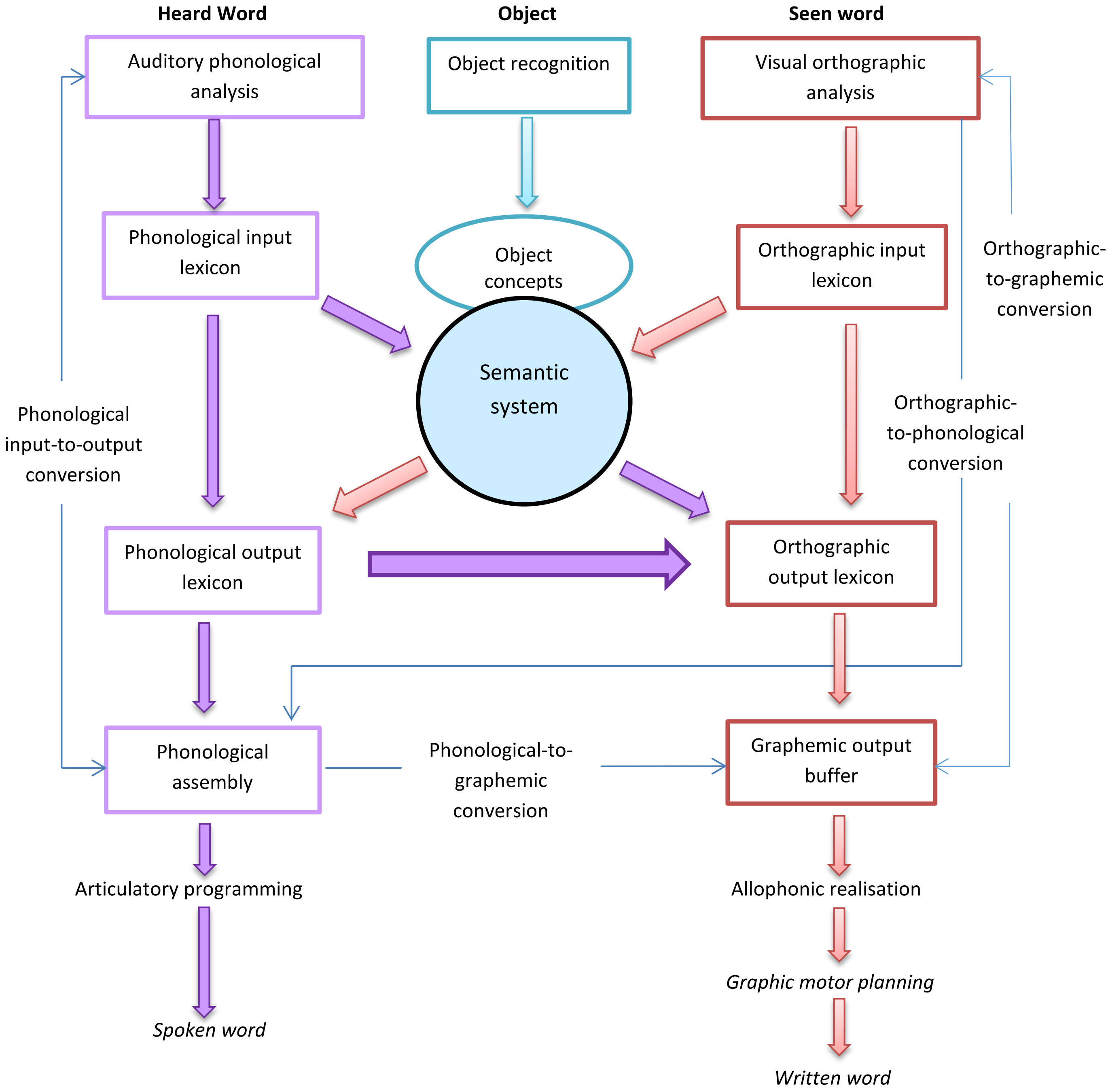

Figure 1.2: A single word model of language processing, based on Patterson and Shewell's logogen model (1987) (adapted from Whitworth et al., 2014).

PWA can experience difficulties with language comprehension due different loci of impairment affecting access to/from semantics, or within semantics itself. As semantics is represented as a central and unimodal component in the Patterson and Shewell (1987) model, if the semantic system is itself degraded then both written and auditory input modalities will be impaired, leading to impaired written and auditory comprehension and production (Ellis & Young, 1996; Funnell, 2002; Whitworth et al., 2014). Non-verbal semantic knowledge (intact object concepts) can be preserved in the absence of intact lexical semantic knowledge, which can be demonstrated through better performance on tests of non-verbal semantic association, such as the Pyramids and Palm Trees test (Howard & Patterson, 1992). Interpretation of this test assumes a view of semantic memory which is composed of partly independent representations for objects and words (Horton & Byng, 2002), however non-verbal semantic processing can also be impaired alongside a lexical-semantic difficulty. Different patterns of impairment and their manifestations in a range of behaviours affecting spoken and written modalities in PWA are briefly summarised in section 1.4.2 to provide background information regarding potential causes of comprehension difficulty in PWA.

1.4.2 Auditory and written comprehension impairment

When applying the Patterson and Shewell (1987) single word model of language processing to impairment of auditory comprehension, there are four main diagnoses that can be considered (Franklin, 1989). It has been proposed that deficits in comprehension can arise from impairment to different aspects of language processing, including auditory phonological analysis, the phonological input lexicon (PIL), access to semantic representations from the PIL or degraded semantic representations in the central semantic system (Franklin, 1989).

On hearing a spoken word, a listener is required to identify and discriminate the difference between presented sounds. Word sound deafness is a term used to describe the effects of damage to the *auditory analysis* level of processing, namely impaired ability to effectively discriminate between sounds accurately, impacting on all subsequent stages of processing. Auditory analysis is tested via minimal pair discrimination tasks, in which the listener hears two words and decides if they are the same word or different words e.g., pin vs bin. Word and nonword repetition is impaired in individuals with word sound deafness but access to semantics can be achieved via written words if the orthographic route is undamaged (Whitworth et al., 2014).

If a PWA has adequate auditory analysis ability but impairment at the level of the *phonological input lexicon*, this is known as word form deafness (Franklin, 1989). The individual may be unable to recognise words as real or nonwords, as demonstrated by auditory lexical decision tasks (for example see patient MK described by Howard & Franklin, 1988), but can repeat sub-lexically and may be able to access semantics orthographically. Deficits at the PIL level can be signalled by frequency effects - that lexical access is speeded for words that occur more frequently in language, as determined by objective counts of word occurrence (Whitworth et al., 2014). Within the literature it is acknowledged that the frequency effect is confounded by additional psycholinguistic variables namely age of acquisition or familiarity effects (Hirsh & Funnell, 1995). It has been demonstrated that words that are acquired at an earlier age are processed more efficiently (Gilhooly & Watson, 1981), for example increased naming speed (Ellis & Morrison, 1998). Familiarity is reported to be a subjective measure of word frequency (Gernsbacher, 1984) or consideration of how much one encounters or thinks about a concept (Snodgrass & Vanderwart, 1980), therefore the more familiar a lexical item or concept, the more efficiently it is processed. This variable is proposed to be a more accurate and reliable measure for low frequency words (Gernsbacher, 1984).

Impaired *access* to semantics from the *phonological input lexicon* is known as word-meaning deafness (Franklin, 1989; Franklin, Howard, & Patterson, 1994; Franklin, Turner, Lambon Ralph, Morris, & Bailey, 1996; Kohn & Friedman, 1986). A post-lexical deficit, here auditory access to lexical semantics from the PIL is impaired and imageability effects are also typically present. This is demonstrated in the cases of DRB (Franklin et al., 1994) and DrO (Franklin, Turner, Lambon Ralph, Morris, & Bailey, 1996). DrO's profile met a classic description of word-meaning deafness, showing good performance at tests of auditory lexical decision but lacking spoken access to the meaning of words, causing poor performance on tests of auditory comprehension such as spoken word to picture matching. This auditory access difficulty is in dissociation to intact access through the orthographic route to semantics. DRB met some of the criteria of word meaning deafness, presenting with impaired repetition. As with all of the comprehension difficulties described thus far, individuals can have retained access to semantic knowledge via written words if the orthographic route remains intact and stable (Whitworth et al., 2014).

Patterns of breakdown in the written modality levels of language processing are summarised below and related to the acquired dyslexias that can occur as part of aphasia. Figure 1.2 highlights the component stages of orthographic single word comprehension, including the levels of visual orthographic analysis, orthographic input lexicon, and semantic system. As described in the dual route model of reading (Coltheart, 2006; Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), it is possible to read words sub-lexically, without meaning, via the orthographic-to-phonological conversion route (e.g. see cases JC & ST: Marshall & Newcombe, 1973). However to comprehend the meaning of a word it needs to be processed via the semantic system.

Impairment in visual orthographic analysis can cause a range of patterns in visual errors in reading, known as peripheral dyslexias (Whitworth et al., 2014), including neglect dyslexia (see case VB: Ellis, Flude, & Young, 1987); attentional dyslexia (Shallice & Warrington, 1977); visual dyslexia (Marshall & Newcombe, 1973) and letter-by-letter reading (Patterson & Kay, 1982). Although discussion of perceptual level impairments are beyond the scope of the current review, deficits at this initial stage of encoding will have effects on subsequent stages of processing, and may thereby prevent access to word meaning, for example through impaired access to the orthographic input lexicon. Central dyslexias affect later stages of processing including the sublexical route of reading, word recognition within the orthographic input lexicon and access to or storage of semantic representations in the lexical route (Whitworth et al., 2014). The central dyslexias will be summarised in turn.

Three main categories of acquired central dyslexia have been described in the literature, surface dyslexia, deep dyslexia, and phonological dyslexia; within each subtype the pattern in reading comprehension difficulty can be attributed to multiple levels of potential breakdown. In surface dyslexia, breakdown in the whole word processing route via lexical semantics causes over-reliance on an intact sub-lexical route (Plaut, McClelland, Seidenberg, & Patterson, 1996). The damage could be prior to semantics in the orthographic input lexicon, which would be apparent on tests of written lexical decision (Ellis & Young, 1996), as in the case of JC (Marshall & Newcombe, 1973; Newcombe & Marshall, 1984). Alternatively the cause of surface dyslexia could be impairment within the semantic system itself, resulting in difficulties in both modalities as described in the case studies HTR (Shallice, Warrington, & McCarthy, 1983) and MP (Bub, Cancelliere, & Kertesz, 1985). Both individuals showed preserved ability to read nonwords via the sub-lexical route and a processing advantage for reading aloud regular words such as *hint* compared to irregular words such as *pint*. Therefore individuals with damage prior to semantics or within semantics will have difficulty accessing meaning via written words, but will be able to read nonwords via orthographic to phonological conversation route (see case KT: McCarthy & Warrington, 1984). Those with post-semantic difficulties due to impaired access to the phonological output lexicon will be able to access meaning (Whitworth et al., 2014).

Conversely, if the sub-lexical route is damaged but the lexical route intact, then this will affect the ability to read new or nonwords, a condition known as phonological dyslexia (e.g. case RG: Beauvois & Dérouesné, 1979; case WB: Funnell, 1983). Reverse effects to surface dyslexia are present, in that there is no effect of regularity and nonword reading is impaired (see descriptions of this pattern in patients with Alzheimer's disease – case RG: Caccappolo-van Vliet, Miozzo, & Stern, 2004a; cases MO and IB: Caccappolo-van Vliet, Miozzo, & Stern, 2004b).

Deep dyslexia may occur when there is damage to both the lexical semantic route and the sub-lexical orthographic-to-phonological conversion route, resulting in semantic, visual or morphological errors in reading, imageability effects (see section 1.4.4) and severely impaired nonword reading. For example, Newcombe and Marshall (1980) describe GR, an individual with aphasia and deep dyslexia. In the written modality GR made semantic errors in word to picture matching tasks and struggled to sort written words into semantic categories.

1.4.3 Summary

Different causes of comprehension impairment are important to consider in relation to semantic processing impairment. Some deficits described directly affect semantic processing in terms of access to semantics or degradation within the semantic system itself, whereas deficits affecting earlier stages of processing as outlined in the Patterson and Shewell model (1987) would cause breakdown in language processing prior to attempted access to semantic knowledge.

1.4.4 Psycholinguistic variables

Studies investigating factors that influence single word processing have highlighted the impact of a range of psycholinguistic variables on semantic processing (Hillis, 2001) that should be considered in assessment, including imageability, concreteness and typicality; these are outlined below.

Imageability refers to how easily a word conjures an image in the mind. Imageability effects constitute preferential processing (e.g., speeded response latencies) for words with high imageability ratings (for example, kitten or tulip) over words with low imageability (for example, decade or favourite). A processing disadvantage has been shown for auditory and orthographic lexical items with lower imageability ratings in control participants (Marcel & Patterson, 1989) and PWA (Richardson, 1975; Frankin, 1989, Nickels & Howard, 1995). The Dual Coding Theory (Clark & Paivio, 1991) has attempted to explain the imageability effect by proposing that low imageability words encode only verbal features whereas high imageability words possess visual and verbal features and therefore possess richer semantic representations. Cases of reserve imageability effects have been reported, where patients have shown an advantage for low imageability words (Warrington & Shallice, 1984), including PWA (Marshall, et al, 1996). These are explained by the existence of different specialised domains within the semantic system for processing different types of information. For example, impairment to visual, action or auditory areas may be more likely to affect words rated as highly imageable.

Correlation between the concepts of imageability and concreteness have been recognised, in that words that are highly imageable are more likely to be concrete, i.e. things that can be experienced through the senses (Crutch & Warrington, 2005a) such as *cherries*, *rabbits* and *telescopes*. Words that are less imageable, are likely to be more abstract, i.e. not directly available to the senses, but perhaps concepts that are more intangible related to emotions or feelings, such as *pining*, *idyllic* and *success*. The categorisation of concrete versus abstract is not regarded as binary however, with lexical items reported to fall on a continuum of concrete to abstract (Crutch & Warrington, 2007). Due to this high correlation, in the aphasia literature the terms imageability and concreteness are often used interchangeably (Franklin, Howard & Patterson, 1994; Marshall et al., 1996). Similar to an imageability effect, a concreteness effect exists, whereby concrete words are processed more efficiently than abstract words. This has been shown in reading with individuals with deep dyslexia, and also in other language domains such as comprehension (Franklin, 1989; Franklin et al. 1994) and naming (Franklin, Howard & Patterson, 1995). Explanations of the source of the processing inferiority of abstract words include their lack of supporting contextual knowledge (Schwanenflugel & Shoben, 1983), lack of sensory referents (Clark & Paivio, 1991), and connectionist approaches which propose fewer semantic features for abstract words compared to the richer representations of concrete words, therefore making them more susceptible to damage (Plaut & Shallice, 1993). An example from the aphasia literature of a processing advantage for concrete words comes from DRB, a patient described by Franklin et al. (1995). DRB demonstrated anomia in conversation, particularly for abstract lexical items. He showed intact access to word meaning through written words, ruling out a central semantic deficit, but impaired repetition of abstract words, highlighting a phonological retrieval difficulty in comparison to repetition of concrete words. There are some cases of inverse effects where performance with abstract words is superior in comparison to concrete words. Patient RG presented with an inverse concreteness effect (Marshall et al., 1996), with impaired comprehension and production of concrete nouns, but relatively preserved processing of abstract items. It was proposed that impairment in the visual domain of the semantic system, which may be more responsible for encoding the features of concrete words, can explain RG's inverse effect, as he presented with poor drawing from memory and the ability to make picture appearance judgements or specify the shape of concrete objects.

Category specific effects can reveal different patterns of degraded semantic knowledge, where patients present with deficits in particular semantic categories compared to others, for example: animals (Blundo, Ricci, & Miller, 2006); fruit and vegetables (Samson & Pillon, 2003; Crutch & Warrington, 2003); people's names as opposed to proper names (Miceli et al, 2000), body parts and geographical names (Goodglass & Wingfield, 1993) (for a review see Humphreys & Frode, 2001). The majority of reported cases have impairments for living or animate things (e.g. animals, plants) versus non-living or inaminate objects (Capitani, Laiacona, Mahon, & Caramazza, 2003). One of the most influential contributions to this area remains the Warrington and Shallice (1984) study of four individuals with herpes simplex encephalitis causing bilateral temporal lobe damage. Although there was variation between aphasic severity and performance on a range of neuropsychological tests, the individuals performed better on language comprehension and production tests with stimuli of inanimate objects, and demonstrated impaired comprehension with animate objects. There were anomalies though, for example, one patient was better at naming inanimate categories however showed specific impairment with instruments and gem stones, whereas body part names were largely intact. The reverse effect of better performance relating to living things compared to non-living has been reported in PWA (for examples see participants PH, Best, Schröder and Herbert, 2006; JJ, Hillis & Caramazza, 1991; CW, Sacchett & Humphreys, 1992; and YOT, Warrington & McCarthy, 1987). Participant PH, a person with post-stroke aphasia, showed the reverse effect of better performance relating to animate things compared to inanimate. Initially testing did not highlight a semantic level impairment, however through detailed psycholinguistic testing and use of reaction time measures in input tasks, semantic impairment was found to be the cause of the pattern (Best et al., 2006).

A typicality effect may also overlap with an imageability effect at a central semantic level of impairment, whereby typical lexical items in a semantic category (for example, wren) possess a processing advantage compared to atypical lexical items (for example, flamingo). The concept of a typicality effect has evolved from the work of Rosch (1975) who reported on the prototype theory that particular members of categories are less or more central than others. For example in semantic verification tasks, longer response latencies to atypical category members compared to typical category members have been reported in unimpaired participants (Larochelle & Pineu, 1994) and PWA (Kiran, Ntourou, & Eubanks, 2007; Kiran & Thompson, 2003). PWA have also shown higher levels of naming accuracy for items in high compared to low typicality word sets in PWA (Rossiter & Best, 2013).

1.5 Access versus storage accounts of aphasia

Early neuropsychological single case studies highlighted the distinction between two types of semantic deficit: disorders of storage in which semantic knowledge is degraded or lost and disorders of access in which lexical semantic knowledge has become inaccessible (Forde & Humphreys, 1995; Warrington & McCarthy, 1983; Warrington & Shallice, 1979). Access deficits have been proposed to account for lexical-semantic processing difficulties in aphasia. Warrington and Shallice (1979) were the first to consider the distinction in acquired language disorders supported by the case of AR, an individual who presented with impaired access to semantics for reading but intact access for writing. Four criteria were suggested to distinguish between storage impairments. i.e. degradation or loss of semantic knowledge, versus access impairments, i.e. where knowledge is present but inaccessible. It was proposed that unlike individuals with semantic storage disorders, individuals with access disorders would show inconsistency of errors between times of testing and tasks, no effects of preservation of superordinate semantic knowledge over subordinate semantic knowledge, no effects of frequency, and stimulability of language via semantic cueing (Warrington & Shallice, 1979). These criteria have been widely applied in the aphasia literature (Moss & Tyler, 1995) and additional phenomena have since been provided as evidence of access impairment. These include: spontaneous recovery (Hula & McNeil, 2008); transient loss of processing capacity for language following transient ischaemic attack (TIA) or other transient neurological episodes such as post-epileptic seizure (Lecours & Joanette, 1980) or migraine (Russell & Olesen, 1996); improvements following neuropharmacological treatment; and creation of aphasic-like impairment in unimpaired speakers. The phenomena described, account for a system of intact semantic representations or other components of language that are inaccessible at different times or across different conditions due to impaired cognitive support systems. This is in comparison to deficits in semantic memory, which are observed in clients with progressive neurological conditions such as herpes simplex encephalitis (Warrington & Shallice, 1984), Alzheimer’s disease (Hodges, Salmon & Butters, 1990, 1992), or semantic dementia (Jefferies & Lambon Ralph, 2006), in which central semantic knowledge is degraded, as demonstrated via impairment across tasks, times of testing and often modality (Jefferies & Lambon Ralph, 2006).

The binary distinction between storage and access impairments has received criticism, for example it is argued that some patients may demonstrate a combination of storage and access effects (Gotts & Plaut, 2002). Further criticisms of studies purporting this distinction were raised by Rapp and Caramazza, (1993), highlighting the potentially limiting nature of single case studies, and fact that all the separate observed behaviours of access versus storage impairments were rarely tested and directly compared in both access and storage deficit patients. However, more recently direct comparisons between groups of patients have been made (Jefferies & Lambon Ralph, 2006; Warrington & Cipolotti, 1996). The bases for access-based explanation of aphasia will be briefly reviewed below.

1.5.1 Variability

People with aphasia often show variability in performance across time on the same task and in the same conditions, which has been cited as evidence of impairment in the underlying cognitive mechanisms causing failed access to intact linguistic information, as opposed to a loss of stored representations and rules of language (Hula & McNeil, 2008). For example, in PWA variability in naming ability (Freed, Marshall & Chulantseff, 1996) and sentence comprehension have been found (Caplan, Waters, DeDe, Michaud, & Reddy, 2007), the latter of which has been assigned to other cognitive processing deficits such as working memory. Kolk (2007) described aphasic behaviour as “inherently variable” (p.101) and stressed the need for models to account for within- and between-subject variability, and further study of the interaction between executive control required for language function, particularly how requirements differ in psycholinguistic testing compared to more naturalistic settings.

Variability in performance is also observed in PWA demonstrating semantic refractory access disorder, as defined by decline in performance or semantic access for a short period after retrieval of semantic information, and decline in semantic processing and accuracy with repeated exposure to items or semantically related stimuli. It is cited as a specific subtype of access difficulty in PWA (Crutch & Warrington, 2005b; Warrington & Cipolotti, 1996; Warrington & Crutch, 2004), in comparison to those with semantic storage deficits. Gotts and Plaut (2002) presented a computational model to account for the storage versus access deficit distinction, in which access difficulties were accounted for by damage to neuromodulatory signals interacting with synaptic depression. Synaptic depression is a version of neural refractoriness where neurons become less responsive for a short amount of time after they have fired. Neuromodulators, such as acetylcholine, support neural activity and reduce synaptic depression, therefore deficiencies of these neurotransmitters would therefore cause a synaptic depression across semantically related lexical items, and the resultant refractory behaviour (Jefferies et al., 2007). Other explanations of refractoriness have looked to the location of damage in the cortex, for example refractory effects in repeated naming paradigms have been found in people with Broca’s aphasia with more frontal lesions than aphasia syndromes with more posterior lesions (Schnur, Schwartz, Brechr, Rossi, & Hodgson, 2006), which could be associated with impairment in semantic control affecting performance on more cognitively demanding tasks, as discussed in section 1.6.1.

1.5.2 Cueing and implicit methods of testing

The effectiveness of cues on naming, as a communicative strategy or as treatment for PWA, (Greenwood, Grassly, Hickin, & Best, 2010) provides further evidence that by providing additional support to the system, successful lexical retrieval can result, suggesting that lexical items were available but inaccessible. Types of cueing found to be successful for some PWA include semantic (Lowell, Beeson, Holland, 1995; Saito & Takeda, 2001) phonological (Jefferies, Patterson & Lambon Ralph, 2008) and orthographic (Best, Herbert, Hickin, Osborne, & Howard, 2002; Lorenz & Nickels, 2007).

Retained knowledge of linguistic information that is unveiled through implicit methods of assessment has been proposed as evidence for a resource allocation deficit as opposed to a loss of linguistic knowledge. Single case studies of PWA have demonstrated retained knowledge of syntactic properties of nouns when the lexical form was not available, such as intact knowledge of grammatical gender (Badecker, Miozzo, & Zanuttini, 1995), for example on language translation tasks (Scarnà & Ellis 2002). Varley, Klessinger, Romanowski and Siegal (2005) present findings of three individuals with agrammatism and severe syntactic impairment in sentence processing tasks who were able to complete syntactic computations in arithmetical tasks. Preserved syntactic ability was demonstrated implicitly, but was not apparent in explicit language production tasks. The authors suggest that language and mathematics is served by a common and domain-general syntactic mechanism, which language representations were unable to access, while mathematics had preserved access.

Priming studies have also contributed to the evidence for access-based explanations of aphasia, with evidence of semantic (e.g. Baum, 1997), syntactic (e.g. Friederici & Kilborn, 1989; Haarmann & Kolk, 1991) and phonological priming (e.g. Wilshire & Saffran, 2005) of lexical or syntactic structures in individuals with aphasia. These provide additional evidence that linguistic information is present and can be activated, therefore linguistic processing systems may account for the difficulties observed in access of this information. Implicit versus explicit methods of assessment of semantics will be further explored in Chapter 2.

1.5.3 Evidence from neurologically intact individuals

It is suggested that by introducing noise into the system of people without aphasia, such as time pressure, dual-tasks or increased task demands, they behave in a linguistically similar way to people with aphasia (McNeil, Hula & Sung, 2011). Aphasic-like errors have been demonstrated with unimpaired participants, in experiments of language comprehension (Just & Carpenter, 1992; Miyake, Carpenter & Just, 1994) and production e.g. category-specific naming effects (Coppens & Frisinger 2005); naming (Hodgson & Lambon Ralph, 2008; Vitkovitch & Humphreys, 1991; Vitkovitch, Humphreys, & Lloyd Jones, 1993) and reading under time constraints (Kello & Plaut, 2000), and picture naming with semantic category decision under time pressure (Silkes, McNeil, & Drton, 2004). Creation of aphasic-like behaviours in PWA when the cognitive system is put under increased demands is cited as further evidence in support of a cognitive processing or access-based account of aphasic impairment, rather than a primarily linguistic or storage based account.

1.5.4 Transience, stimulability and treatment

Spontaneous improvement of aphasic symptoms in the initial phases of stroke recovery occurs for many clients (Lendrem & Lincoln, 1985; Pedersen, Jørgensen, Nakayama, Raaschou, & Olsen, 1995). This transience of aphasia in recovery of some individuals post-stroke and in TIA, seizures and migraine, as well as the stimulability of language through repetitive transcranial magnetic stimulation (rTMS) and successful outcomes following neuro-pharmacological treatment of aphasia, are all cited as evidence that language is not degraded but that support systems are impaired, for example the cognitive resources necessary to compute language (Hula & McNeil, 2008).

Repetitive transcranial magnetic stimulation (rTMS) studies have demonstrated stimulability of language abilities following inhibition of the right-hemisphere homologue for language, which is proposed to inhibit over-activation of right hemisphere language homologues, thus allowing reactivation of areas in the damaged left hemisphere (Barwood et al., 2011; Martin et al., 2009; Naeser et al., 2011). Aphasic symptoms have also been shown to improve following neuro-pharmacological treatment. For example, trials of dopaminergic agents for cognition in cocaine-associated stroke may improve the dopaminergic pathways damaged by cocaine use, thus improving attention and initiation (Tolat, O'Dell, Golamco-Estrella, & Avella, 2000). A further study investigated the use of amphetamine in aphasia recovery in a double-blind placebo controlled study (Walker-Batson et al., 2001). In ten sessions over a five week period participants received either an oral dose of dextroamphetamine or placebo oral substance each followed by speech and language therapy. There were significantly greater gains on language measures in the dextroamphetamine group from one week after the end of the drug treatment. It is suggested that such findings provide evidence against a complete loss or inaccessibility of linguistic knowledge, and instead support the notion of an inaccessible language system; although the mechanisms by which language is inaccessible is debated (Hula & McNeil, 2008).

1.6 Explanations of access difficulties in aphasia

The impact of other cognitive-based explanations of access deficit in aphasia have been proposed, and are subsequently summarised. McNeil and colleagues (Hula & McNeil, 2008; Hula, McNeil, & Sung, 2007; Tseng, McNeil, & Milenkovic, 1993) suggest that the language behaviours manifested in aphasia may be due in part to impaired attention and working memory necessary to *do* language rather than a primarily linguistic deficit (McNeil et al., 2011). Other lines of research though, suggest that cognitive impairment can contribute to the impairment in aphasia, including deficits in attention (e.g. see Murray, 1999 for a review), short term memory (e.g. see Minkina, Rosenberg, Kalinyak-Fliszar, & Martin, 2017 for a review) working memory (e.g. see Salis, Hwang, Howard, & Lallini, 2017 for a review) and executive function (see Murray, 2017). Of particular relevance to the storage versus access to semantic knowledge debate, is the discussion regarding the executive control of semantic processing, as presented by Jefferies and Lambon Ralph (2006).

1.6.1 Semantic control

Jefferies and Lambon Ralph (2006) were the first to directly compare individuals with semantic dementia (SD) and individuals with semantic aphasia (SA) using a case series methodology, supplementing the explanations of semantic access disorder in aphasia with a proposal that the impairment to semantic processing in SA is due to reduced executive semantic control. The two patient groups scored similarly on a range of semantic assessments, however qualitative differences in performance were found, which overlap with storage/access criteria introduced by Warrington and Shallice (1979) and support the notion that in SD semantic representations are degraded or lost, whereas in SA they are at times inaccessible. The SD group showed consistency in performance on specific items independent of the modality in which they were tested, and sensitivity to frequency/familiarity, which according to Rogers et al. (2004) implicates a degradation of amodal semantic representations, in which items of higher frequency are preserved for longer into the course of the disease. The SA group also showed consistent performance within tasks across modalities (e.g. the picture versus word versions of the Pyramids and Palm Trees test), but scores between different input semantic tests were not consistent (e.g., on picture tests of semantic association versus word to picture matching tests). The SA group did not show the frequency/familiarity effects of the SD group. In addition, the SA group responded to phonemic cues on picture naming, whereas the SD group did not, suggesting that lexical semantic representations were degraded for the SD group but were accessible with support for the SA group.

Moreover, the SA group also made semantic associative errors (e.g., squirrel-nuts) that were not made by the SD group and are not in line with a typical error pattern seen with a gradual loss of knowledge. Finally, for the SA group only, there were significant correlations between scores on semantic tests (word to picture matching, Pyramids and Palm Trees and picture naming) and an executive skill factor (Coloured Progressive Matrices test [Raven, 1962] and the Wisconsin Card Sorting Test [Heaton, Chelune, Talley, Kay, & Curtis, 1993]). The authors hypothesise behaviours demonstrated in the SA group signal impaired control of or loss of flexibility in access to semantic information, as demonstrated on tasks with higher control demands such as lexical-semantic association tasks as opposed to tests of word to picture matching. The executive control demands in a word to picture matching task, where the target is selected amid competition from semantic distractors, are different to those required in the three pictures Camel and Cactus semantic association task, in which individuals have to evaluate associations between a target picture and distractor picture, pinpointing which features of the concepts are pertinent. The latter requires a significant amount of inference ability (Lambon-Ralph, Snell, Fillingham, Conroy, & Sage, 2010), for example to match a strawberry to people playing tennis, sensory information about strawberries is irrelevant, whereas knowledge about the tennis tournament Wimbledon is paramount.

The distinction between the SD and SA group behaviours and proposed loci of impairment were further supported by their different regions of brain damage; SD patients had bilateral anterior temporal lobe atrophy affecting semantic knowledge, whereas the SA group had a combination of left frontal and temporo-parietal lesions, suggesting that temporo-parietal areas may have a role in executive semantic control (Jefferies & Lambon Ralph, 2006; Jefferies et al., 2007), affecting comprehension. Neuropsychological and imaging findings support this viewpoint as both areas are shown to be involved in executive functioning (Garavan, Ross, Li, & Stein, 2000; Peers et al., 2005).

1.6.2 Summary

As discussed, language processing, in particular semantic processing, is dependent on the integrity of supportive cognitive functions, and impairment in any of these may contribute to an aphasia profile. Whilst distinct brain regions are responsible for different cognitive and linguistic functions, these have been shown to work together in order to process language in an integrated and interactive way (Villard & Kiran, 2016). The relationship between language and other aspects of cognition, including attention, memory and executive function will now be considered in relation to aphasia, including how they can be tested in this population.

1.7 Language and other cognition

Cognition is a global term for a range of cognitive functions such as attention, memory, language and executive function. These mental processes are responsible for the acquisition, storage, retrieval and manipulation of information and regulation of behaviours, which work together to control many activities in daily life. For example, language falls within the domain of cognition but is supported by other cognitive functions which operate synergistically; this synergism contributes to the difficulty in assessing cognitive domains as unitary concepts (Miyake & Friedman, 2012).

Post-stroke cognitive impairment is associated with poorer long-term outcomes (Patel, Coshall, Rudd, & Wolfe, 2002) including activities of daily living (Zinn et al. 2004) and quality of life (Kwa, Limburg, & Haan, 1996). A relationship between aphasic language ability and cognitive ability has also been reported in the literature (Kalbe, Reinhold, Brand, Markowitsch, & Kessler, 2005; Lee & Pyun, 2014). A number of studies have argued for a relationship between aspects of cognitive function and semantic processing in PWA, including attention (Hunting-Pompon, Kendall, & Bacon-Moore, 2011; Murray, 2012, 2000; Murray, Holland, & Beeson, 1997a; Tseng, McNeil, & Milenkovic, 1993; Villard & Kiran, 2016, 2015), memory (Albert, 1976; Ivanova, Dragoy, Kuptsova, Ulicheva, & Laurunavichyute, 2015; Salis et al., 2017; Yasuda, Nakamura & Beckman, 2000) and executive function (Allen, Martin, & Martin, 2012; Beeson, Bayles, Rubens, & Kasniak, 1993; Glosser & Goodglass, 1990; Murray, 2017; Purdy, 2002). Assessment of aspects of cognition which interface with language processing are increasingly being investigated in research with people with aphasia, due to their potential impact on rehabilitation (Helm-Estabrooks 2002; Keil & Kaszniak, 2002; Murray, 2012b). A number of recent studies have reported correlations between tests of cognitive skills and language recovery post-stroke, such as attention (Lambon Ralph et al., 2010) visuospatial working memory (Seniów, Litwin, & Leśniak, 2009), executive function (Fillingham, Sage, & Lambon Ralph, 2005a, 2005b, 2006), and tests which arguably tap a range of cognitive functions e.g. the Rey Complex Figure Test (Conroy, Sage & Lambon Ralph, 2009), a measure of visuospatial skills, short term visual memory, attention and planning (Lezak, Howieson, & Loring, 2004).

Assessment of other cognition in addition to language is particularly challenging in PWA due to the confound of linguistic load in cognitive tasks (Mayer & Murray, 2012). This includes written and spoken understanding of sentences in task instructions, language used in preparing a response or to mediate problem-solving, and actual verbal output required for task success.

Despite this, cognitive tests that require language comprehension and expression are used as accepted measures of cognitive constructs with PWA. Although it is challenging to completely remove language from cognitive tests, some attempts have been made to reduce the reliance on language in testing, to enable the assessment to be a valid measure of specific cognitive skill. In light of the possible relationship between semantic processing and cognitive functions, a review of cognitive skills and their assessment in PWA will be discussed in the following subsections.

1.7.1 Attention and aphasia

Different types of attention are required for linguistic and non-linguistic tasks, and attentional deficits in PWA have been widely reported. Correlations between language comprehension and attention have been demonstrated (Wiener, Tabor Connor, & Obler, 2004). There is growing evidence that attentional functions can be compromised in PWA, as demonstrated in non-verbal tasks (Erickson, Goldinger, & LaPointe, 1996; LaPointe & Erickson, 1991; Villard & Kiran, 2015), which may also impact on language capabilities, thus affecting performance on language assessment. In considering the impact on wider activity and participation (World Health Organisation, 2001), a study by Ramsing, Blomstrand and Sullivan (1991) identified post-stroke impairments of attention as having more impact on return to work than language impairments for some participants. Attention is not routinely assessed or treated by speech and language therapists, however for PWA, attentional deficits may also be impacting on their language capabilities and outcomes of speech and language therapy (Lambon Ralph et al. 2010). Treatment plans combining linguistic tasks in the context of attention training have shown some preliminary positive results for PWA (Peach, Nathan & Beck, 2017).

Sustained attention requires a consistent behavioural response to be maintained over time and is necessary in long or repetitive tasks (Murray 1999). Glosser and Goodglass (1990) found that in a non-verbal visual sustained attention task of responding to a letter ‘X’ or ‘O’ presented in a continuous random string of these letters, people with left hemisphere (particularly frontal) lesions and aphasia performed worse than control participants, whereas the right-hemisphere lesion group performed worse at visuo-spatial tasks. Visual sustained attention has also been found to be implicated in PWA when performing a cancellation task from the Global Aphasic Neuropsychological Battery (GANBA) (van Mourik, Verschaeve, Boon, Paquier, & Harskamp, 1992). In smaller studies of auditory tone discrimination no significant differences in sustained attention were found between people with aphasia and control groups (Erickson, Goldinger, & LaPointe, 1996; Murray et al., 1997a; Murray, Holland, &

Beeson, 1997b). An impairment in sustained attention is likely to impact on semantic processing functionally in terms of difficulty maintaining attention in conversation (Frankel, Penn & Ormond-Brown, 2007) or in reading comprehension (Sinotte & Coelho, 2007).

Divided attention is perceived to be a more complex process requiring an individual to attend and respond to more than one simultaneous channel of input (Murray, 1999; O'Donnell, 2002), for example driving while having a conversation. Differences in divided attention between PWA and control groups have been demonstrated. This area of research often uses a dual-task paradigm to investigate divided attention across two tasks to investigate capacity-based explanations of aphasia, with a participant completing one linguistic task in competition with another task, which may be linguistic or non-linguistic in nature. It is argued that amount of dual-task interference demonstrates the degree to which the two tasks are competing for a pool of attentional resources (Murray, 1999). In an experiment involving the dual tasks of grammaticality judgement and tone discrimination, Murray et al. (1997b) found a PWA group to perform more slowly at tone discrimination as the attention demands increased i.e. ranging from without distraction, to focused attention, to divided attention, with the grammaticality judgement linguistic task. Erickson, Goldinger and LaPointe (1996) found a similar pattern when using a non-linguistic dual-task of tone discrimination and card-sorting when comparing PWA and a non-brain damaged control group; as soon as the attention was divided between two tasks a significant group difference in performance occurred, with PWA demonstrating impaired performance. Activities requiring sustained attention are also likely to require some level of divided attention when performed alongside competing everyday interruptions or environments with competing demands (Murray, 2000), therefore daily activities requiring semantic processing and language comprehension, such as managing conversation or reading a novel, may be negatively affected by a deficit in divided attention in PWA.

Selective attention requires focus on a stimulus or behaviour while inhibiting processing of another or others, for example focusing on reading while ignoring music playing in the background. This is particularly relevant to the consideration of PWA performance on tests of semantic processing, where individuals may need to selectively identify a target word or picture, whilst inhibiting responses to distractors. If PWA struggle to sustain or provide selective attention to words and pictures in semantic testing then the ability to process the stimuli will be affected in assessment (Villard & Kiran, 2016), potentially resulting in a test score that misrepresents semantic processing ability. Impaired ability to maintain and switch attention during therapy sessions may also consequently affect communication rehabilitation (Villard & Kiran, 2015).

A further line of research in attentional difficulties in aphasia has investigated whether resources may be independently misallocated as opposed to, or in addition to, lacking in capacity (Hula & McNeil, 2008). It is argued that people with aphasia and non-brain damaged individuals have similar language capacity, but individuals with aphasia cannot allocate their attentional resources appropriately (McNeil, Odell, & Tseng, 1991). Tseng et al. (1993) investigated the ability of nine PWA and eighteen control participants to perform a dual-task of semantic judgement and phoneme monitoring. Participants were told the probability of target occurrence in the explicit condition, and not in the implicit condition. It was hypothesised that if participants were told to expect more semantic targets they would allocate more resources to semantic identification, optimising their performance. In the dual-task the control group showed this effect however the PWA group did not, despite performing better at the semantic judgement in the single-task condition. It was therefore proposed that the PWA were impaired at allocating their attention efficiently rather than lacking in capacity.

1.7.1.1 Assessment of attention in PWA

Methods of assessment for attention such as the Stroop test (Trenerry, Crosson, DeBoe, & Leber, 1989) or other standardised tests of attention are unlikely to be valid for people with aphasia due to the large linguistic processing load that they entail (see Murray, 2002 for a review) however there have been attempts to make aphasia-accessible versions (Wiener et al., 2004). The Test of Everyday Attention (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994) is useful in that it assesses different types of attention such as sustained, selective and divided, and has been standardised with stroke patients (Murray, 2002), however its validity for use with PWA can still be questioned due to the linguistic processing required for successful performance.

1.7.2 Short-term memory, working memory, and aphasia

Short term memory (STM) can be defined as the ability to retain small amounts of information over brief periods of time (Baddeley, 2015a) which may relate to visuo-spatial information or verbal information, with the support of the phonological loop /articulatory rehearsal for the latter (Baddeley & Hitch, 1974). Short term memory has since been reconceptualised as one element of working memory, a more complex system proposed to underlie thought that involves both storage and manipulation of information (Baddeley, 2003a). A contemporary and generally accepted construct of working memory includes a central executive assumed to direct attention and allocate resources within the three storage systems: the visuospatial sketchpad, the episodic buffer and the phonological loop (Baddeley, 2000). The phonological loop is proposed to be a speech-based storage buffer where articulatory rehearsal can take place, whereas the visuospatial sketch pad provides temporary storage for visual, spatial and potentially kinaesthetic information, and the episodic buffer holds, integrates and binds information and is reliant on executive processes and accessible to conscious awareness (Baddeley, 2000; Baddeley, 2015b). The phonological loop is believed to play a key role in language acquisition and learning, whereas the visuospatial sketchpad may have a role in reading, for example sustaining a representation of the page layout (Baddeley, 2003b). In a language-based model of STM, it is suggested that in addition to the phonological buffer for retention of verbal information, a lexical semantic buffer exists (Martin, Shelton, & Yaffee, 1994; Martin & He, 2004) which maintains lexical-semantic information (Martin & Saffran, 1997.)

Concomitant impairment in short term / working memory often accompanies aphasia (Caplan, Michaud & Hufford, 2013; Salis et al., 2017; Wright & Fergadiotis, 2012) and deficits in short-term memory have been found to affect lexical semantic processing. Martin, Kohen, Kalinyak-Fliszar, Soveri, and Laine (2012) found a relationship between increased verbal STM load and reduced performance on synonym judgement tasks; multiple regression analyses found that both semantic STM and one executive function measure of inhibition were the strongest predictors for synonym judgement performance.

Links between impaired sentence comprehension in PWA and impaired phonological working memory (Caplan et al., 2013) and semantic working memory (Martin & Allen, 2008) have been proposed, however single case studies are reported in which impairment of short term memory is dissociated from single word semantic processing ability (see cases AB: Martin & Romani, 1994; Martin, Shelton, & Yaffee, 1994; and ML: Martin & Freedman, 2001; Martin & He, 2004). Shared neural substrates of the left posterior superior temporal gyrus have been identified for auditory short term memory and auditory sentence comprehension (Leff et al., 2009), with the integrity of this region impacting on sentence comprehension capacity. For a review of the relationship between working memory and sentence comprehension see Salis et al. (2017).

In a study with PWA, Harnish and Lundine (2015) found that visuospatial working memory abilities predicted response to anomia therapy. Salis (2012) reported treatment effects of training verbal short term memory had a positive impact on sentence comprehension but not on single word comprehension. Verbal working memory ability has also been shown to impact on text-level reading comprehension in individuals with a mild aphasia (Meteyard, Bruce, Edmundson, & Oakhill, 2015).

1.7.2.1 Assessment of short term and working memory in PWA

Testing for STM in PWA is often also confounded by linguistic task requirements. Typically a forwards digit span is used to assess verbal short term memory (Leff et al., 2009), specifically the phonological loop (Baddeley, 2000). In a digit span task participants are required to listen to a string of digits of increasing number per presentation, and then repeat them back in the same order, thus demonstrating the auditory short term memory store capacity. To measure working memory, a backwards digit span task can be used, as a measure of individual's ability to hold and manipulate information of increasing amounts, thought to involve additional executive function requirements to manipulate information in a temporary storage or buffer (Lezak et al., 2004). The applicability of these tasks for PWA is limited due to linguistic task requirements, such as articulatory rehearsal and the repetition of verbal information, making it difficult to separate the impact of language or working memory contributions to task performance (Mayer & Murray, 2012). Alternative tasks with reduced linguistic components have been proposed, such as an *n*-back task (Jonides et al. 1997), which will be discussed below in the context of assessment of cognition as a whole.

Working memory is often assessed as part of attention, as the two constructs are perceived to be difficult to distinguish in assessment, and both have a role in language processing (Kurland, 2011). For example, the elevator counting with distraction subtest of the Test of Everyday Attention (Robertson et al., 1994) is deemed by some to assess auditory selective attention and auditory-verbal working memory (e.g. Peach et al., 2017).

The *n*-back task has been developed as an assessment of working memory (Jonides et al., 1997). In this task individuals decide if an item presented on a computer screen is the same item that appeared *n*-back, *n* always being a number. For example, if the rule given is 2-back and visual presentation was circle-triangle-circle, then on seeing the second circle the participant would press a response button, as circle was already presented 2 items back. Christensen and Wright (2010) investigated this task with PWA, who demonstrated impaired performance compared to the control group on three tasks in which the stimuli varied in terms of linguistic load. Like the control group, as the stimuli became less easy to assign meaning or phonological form to, PWA's performance declined. For example, they performed better at a task involving fruit, than one involving novel objects or blocks of three-dimensional coloured cubes connected into different formations. From this the authors claim that, in addition to language deficits, other cognitive deficits are present in PWA. A more recent study used pictures of neutral facial expressions in the *n*-back task for PWA in an attempt to further diminish linguistic requirements from the task through use of non-nameable stimuli (Mayer & Murray, 2012), however the requirement of counting still remained. In this task both control participants and PWA performed less accurately in the facial expressions condition in comparison to an *n*-back task with object pictures, with the PWA group showing steeper decrements in performance as the working memory load increased to the 2-back condition.

1.7.3 Executive function and aphasia

Executive function is the term used to describe the cognitive system that controls and regulates other cognitive processes, including language, attention and memory, and ultimately allows individuals to flexibly participate in purposive and independent behaviour (Lezak, et al., 2004). The exact nature of executive function continues to be elusive however (Jurado & Rosselli, 2007), with a lack of consensus also within the aphasia literature (Miyake, Emerson, & Friedman, 2000). Terms used to classify executive function, include organisation, planning, inhibition, problem solving, sequencing, cognitive flexibility, and self-monitoring goal directed activity. These are all established as frontal lobe activities (Murray & Ramage, 2000; Purdy, 2002), however it is recognised that many of these sub-processes require overlapping skills, and lack definition themselves. Neuroimaging techniques have shown overlap between language and executive functioning in terms of neural pathways and structures, including the left inferior frontal gyrus, superior longitudinal fasciculus, with lesions in these areas resulting in language and executive function difficulties (Murray, 2017; for a review see Cahana-Amitay & Albert, 2015), suggesting interactions between the systems.

Executive function impairments often occur concomitantly with aphasia (Hoffman, Jefferies, Ehsan, Jones, & Lambon Ralph, 2012; Martin & Allen, 2008; Murray, 2012; Murray, 2017; Zakariás, Keresztes, Demeter, & Lukács, 2013). The importance of considering executive function difficulties in PWA has recently been highlighted by a number of studies demonstrating significant relationships between executive functioning and language comprehension (Chesneau & Ska, 2015), word-finding (Penn, Frankel & Wilkinson, 2015), functional comprehension and production (Frankel, Penn & Ormond-Brown, 2007; Fridriksson, Nettles, Davis, Morrow, & Montgomery, 2006) and strategies in conversation (Purdy & Koch, 2006). Allen, Martin and Martin (2012) also reported relationships between executive functioning and semantic processing tasks, including a spoken word to picture matching task (The Peabody Picture Vocabulary Test-Revised [Dunn & Dunn, 1981]) and a nonverbal test of semantic association (the three picture version of the Pyramids and Palm Trees [Howard & Patterson, 1992]).

1.7.3.1 Assessment of executive functioning

Assessment of executive functioning and its component parts is challenging, particularly in relation to PWA for whom linguistic processing may be a barrier to task comprehension and performance (Penn, Frankel, Watermeyer, & Russell, 2010). A limited range of tests are used clinically and within research to test for executive functioning in PWA (for a summary see Murray & Ramage, 2000). Two tests reported as measures of executive function have been found to correlate with language ability in aphasia. For example, PWA performance on the nonverbal measure of executive function, the Wisconsin Card Sorting Test (WCST: Berg, 1948; Grant & Berg, 1993), has been found to predict naming therapy outcomes (Hinckley & Carr, 2001; Fillingham et al., 2005a, 2005b, 2006). Performance on the WCST and Ravens Coloured Progressive Matrices (Raven, 1956) have also been related to PWA language profiles of naming and comprehension (Baldo et al., 2005).

In the WCST cards are presented which depict stimuli that vary in terms of shape, colour and number; participants are presented with four cards for reference and then are required to sort the remaining cards by ascertaining the rule for sorting. Feedback is provided on the accuracy of their sorting rule, however the task requirements are made more challenging as the examiner changes the rule every 10 cards without communicating this explicitly. This is categorised by Murray and Ramage (2000) as an organisation executive function task. The Raven's Progressive Matrices (Raven, Court, & Raven, 1985; Raven, 1956 - coloured) have been categorised in the literature as problem solving tests, also assessing visual perceptual skills (Muray & Ramage, 2000). Participants are presented with a design with a piece missing, and then choose from a selection of options, of which, one is the correct match for the missing space. Apart from the requirement of understanding the task instructions it is considered to be a nonverbal task, however performance may in fact benefit from verbal mediation, which is arguably less available to PWA (Lezak et al., 2004). Some research studies have shown no correlation between Raven's scores and aphasia severity (e.g. Kertesz & McCabe, 1975), whereas others have reported a relationship with severity of aphasia (e.g. Grigoroiu & Mihailescu, 1979).

In the aphasia literature, three less frequently used measures of executive function include trail making tasks (originally Reitan & Wolfson, 1985), the Tower of Hanoi task (Simon, 1975) and Tower of London tasks (Miyake et al., 2000; Shallice, 1982). Trail tasks are described as assessing cognitive flexibility, whereby participants are required to shift from one focus to another, dependent on internal or external feedback (Murray & Ramage, 2000). Originally based around the requirement to connect digits with lines, or digits and letters, based on an alternating pattern, the trails task has since been adapted to entail less linguistic load through use of shapes (see the Symbol Trails subtest in the Cognitive Linguistic Quick Test [CLQT], Helm-Estabrooks, 2001).

The Tower of Hanoi task (Simon, 1975) has been categorised as a planning executive function task (Murray & Ramage, 2000). Neuroimaging studies have highlighted a substantial role of the prefrontal cortex in task performance (Lazeron et al., 2000; Baker et al., 1996). Participants are presented with three poles, with a number of disks in a configuration of increasing size on the left-hand pole (see Figure 1.3). Participants are required to move the disks one at a time to finish with the same initial configuration of disks, but repositioned onto the right-hand pole. Additional rules specify that a larger disc cannot be placed on top of a smaller disk, and that participants should attempt the task in the fewest number of moves. A variant of the task also exists, the Tower of London task (Shallice, 1982), in which the disks are of equal size but the length of each pole is different affecting the number of discs that can be held.

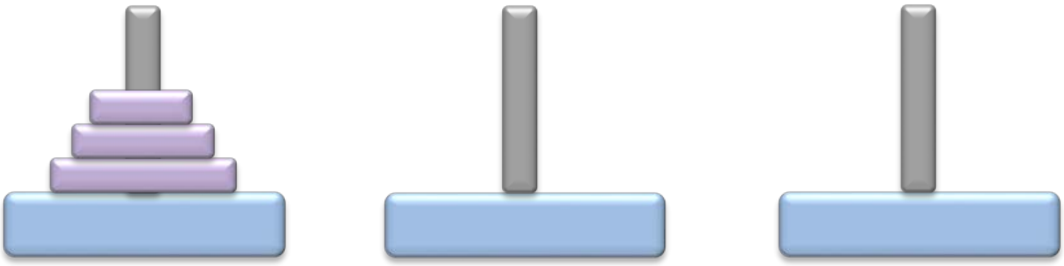

Figure 1.3: Example of a task from Towers of Hanoi - 3 discs

Although planning is required for successful Towers of Hanoi task performance, the construct validity (i.e. what skills are these assessments tapping) has been questioned (Miyake, 2000), and as in all executive function tasks, other cognitive skills are assumed to be implicated including working memory, visuospatial memory and response inhibition (Lezak et al., 2004). In addition it has been argued by Goel and Grafman (1995) that rather than planning, the key strategy required includes the need to look beyond the final goal and establish subgoals, inhibiting the prepotent response and at times making counterintuitive moves which may not place a disc in its final required position but it essential for solution of the task. Low reliability is another potential concern with executive function tasks, for example Humes, Welsh, Retzlaff and Cookson (1997) highlight a lack of evidence for the Towers of Hanoi task reliability, and Bowden et al., (1998) found low reliability of performance measures with student participants completing the WCST.

Verbal fluency is reported as a further measure of executive function, in the category of self-monitoring (Murray & Ramage, 2000), as individuals are requested to generate or cluster words within a semantic category (e.g. animals) or beginning with a certain letter, to track which words they have already produced, and switch to a new category when members of a subcategory is exhausted (Tröster et al., 1998; Troyer, Moscovitch, & Winocur, 1997). However, the use of this task with PWA is somewhat confounded, due to the linguistic requirements for successful task performance. A study by Whiteside et al., (2016) used exploratory factor analysis to compare the role of executive function and language ability on verbal fluency, reporting that verbal fluency tasks highly correlated and loaded onto the language factor in non-aphasic participants with other neurological diagnosis (e.g. acquired brain injury, multiple sclerosis, dementia or primary psychiatric diagnosis), suggesting that the task success primarily relies on language rather than executive function (as measured by a trails tests and WCST). Bose, Wood and Kiran (2017) provide further evidence in support of this claim with control and PWA samples of animal fluency tasks. The authors found that the task was more effortful and less productive for PWA, characterised by smaller numbers of exemplars in each category, fewer switches, increased pausing between switches, and slower retrieval time. This supports the view that in PWA, performance on semantic fluency tasks relies primarily on lexical retrieval skills with some components of executive function, as shown by difficulty switching.

As an alternative to the verbal fluency task, Murray (2017) trialled the use of the Ruff Figural Fluency Test (RUFF - Ruff, 1996) as a nonverbal self-monitoring task with PWA. Within this task, PWA were presented with a piece of paper with 40 squares, each square containing five dots, and asked to generate as many different designs as possible in one minute, by joining the dots with lines. Significant variation within the PWA group was found, with heterogeneity in the severity of the executive functioning problems observed in the task, with some PWA showing no impairment, and also a lack of relationship between RUFF performance and language ability.

1.7.4 Summary: language and other cognition in PWA

Impairment in other cognitive functions are reported in PWA. The potential contributions of deficits in attention, short term memory, working memory, and the multifaceted concept of executive function, are challenging to extricate from PWA performance in tests of semantic processing. Assessment of these aspects of cognition is also challenging in PWA, due to the linguistic task requirements and the difficulty in isolating specific cognitive skills in assessment, which typically work in an integrated way.

1.8 Chapter summary

Chapter 1 has described different explanations of apparent aphasic semantic impairment in relation to a single word model of language processing and with reference to the proposal that access to stored semantic knowledge may be impaired in aphasia rather than the knowledge itself being degraded; cognitive deficits including impaired executive control of semantics are considered as explanations. These lines of enquiry necessitate consideration of the role of cognition and executive functioning in aphasia and the interaction with language that may result in or contribute to the presenting language impairment, as well as the cognitive and executive requirements of semantic processing tasks and how these may impinge on performance.

The specific identification of level of breakdown in language comprehension or other cognitive functioning is essential to enable correct diagnosis for PWA. Ultimately, identification and implementation of appropriate intervention choice is reliant on accurate diagnosis, thus ensuring the best possible communication rehabilitation outcomes for PWA. In Chapter 2, methods of testing semantics will be explored, including an alternative measure to traditional language testing, semantic priming; an implicit method of assessing semantic processing.

Chapter 2 Assessment of semantics

2.1 Explicit versus implicit testing

Explicit or 'offline' tasks involve controlled and conscious decisions often reliant on problem solving or metalinguistic processing. The aphasia assessments described in Chapter 1 are explicit tasks, in that they require individuals to make explicit and conscious reflections about word meanings to demonstrate their ability or knowledge e.g. 'which of these pictures matches the word I just heard?' or 'how is a kangaroo similar to a trampoline?' (Shaprio, Swinney, & Borsky, 1998). Such explicit language judgements require conscious reflection that is usually absent from naturalistic language comprehension (Greene & McKoon, 1995); they do not take place in real-time, unlike typical spoken comprehension in which words and sentences are heard at a fast rate and processed automatically (Shapiro et al., 1998). In addition, many explicit language tasks are dependent on cognition external to language, which could therefore result in inaccurate estimation of language ability dependant on the status of the individual's cognitive or metalinguistic skills (Marinis, 2010; Milberg & Blumstein, 1981; Shapiro et al., 1998). The term *explicit* will be used throughout to refer to this concept.

In implicit or 'online' language tasks, knowledge is accessed and measured without individuals' conscious awareness. A participant's response may be temporally related to a particular linguistic variable, with the task thought more to reflect the automatic and unconscious elements of language processing (Karmiloff-Smith et al., 1998). A range of research methodologies exists whereby semantic activation can be measured implicitly. Behavioural tasks, such as semantic priming, can be used as a measure of semantic processing through analysis of reaction time data. Online neuroimaging techniques can also provide implicit measurements of neural activity that reflect real-time semantic processing. Eye-tracking is a further implicit measure that has been used to study language processing (for a review see Huettig, Rommers, & Meyer, 2011) and specifically semantic activation in word to picture matching tasks (Yee & Sedivy, 2006).

Chapter 2 will explore currently available explicit lexical semantic assessment methods. Implicit methods of assessing semantic knowledge will then be considered, through description of the semantic priming paradigm, concluding with how it can be applied to PWA.

2.2 Explicit methods of semantic assessment in aphasia

In the United Kingdom, the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA: Kay et al., 1992) is reported to be the most common language assessment used by clinicians to assess PWA (Katz et al., 2000). However, the PALPA has received some criticism, for a lack of normative data or descriptive statistics, and lack of control of psycholinguistic variables of stimuli (Cole-Virtue & Nickels, 2004a). More recently, the Comprehensive Aphasia Test (CAT: Swinburn, Porter, & Howard, 2004) has been published, providing a standardised assessment of language processing including spoken and written word to picture matching subtests (Bruce & Edmundson, 2010). The Boston Diagnostic Aphasia Examination (Goodglass, Kaplan & Barresi, 2001) and the Western Aphasia Battery (Kertesz, 2006) are reported to be more commonly used in countries such as the United States, Canada and Australia (Katz et al., 2000). Formal assessment remains limited for non-English speaking PWA, or where English is not the primary language, as clinical and research developments in aphasia remain limited in many countries (Ivanova & Hallowell, 2013). Some assessments are translated from English to alternative languages which pose problems, for example the lack of culturally relevant stimuli or change in psycholinguistic variables for the test items (Ivanova & Hallowell, 2013). Currently researchers are adapting assessments to be suitable for other languages, for example the CAT, including assessment batteries for Qatari/Gulf Arabic speakers (Khwaileh, Mustafawi, Howard, & Herbert, 2016), and creating new assessments in non-English languages, for example a semantic processing battery in Malay (Jalil, Rickard Liow, & Keng, 2011). Within test batteries, particular assessments designed to assess lexical semantic processing include word to picture matching (WPM), word to picture verification (WPV), synonym judgement and semantic association tasks. In the former two tests, semantic distractors tend to be used, for example items from the same semantic category (i.e. items of the same kind such as *dog-cat*; Lin & Murphy, 2001), whereas in semantic association tasks the relationship between targets and distractors are based on association (i.e. lexical co-occurrence or situational co-occurrence of entities in the world (Moss, Ostrin, Tyler, & Marslen-Wilson, 1995).

In WPM, individuals hear or read a single word and match it to a picture, in the presence of related distractor pictures (e.g. PALPA, Kay et al., 1992; CAT, Swinburn et al., 2004). Using a literature search and a clinician survey, use of the PALPA was examined across 1991-2009, and the spoken WPM task was found to be the most commonly used subtest (Bate, Kay, Code, Haslam & Hallowell, 2010). The WPM subtest has received particular attention with regard to its lack of standardisation (Wertz, 1996), which could have implications for interpretation of test performance. In fact, the authors note that they did not carry out sufficient measures of reliability or validity (Kay et al., 1996), and others have subsequently attempted to assess the internal validity of the test. Kay et al. (1992) chose distractors based on differences in semantic relationships for example, target - *carrot,* close semantic relation - *cabbage*, visually similar semantic error - *peeler,* distant semantic relation - *lemon,* and unrelated distractor - *saw*. They argued that patterns in test performance highlight types of semantic errors: visual errors would signify a perceptual deficit; more errors involving selection of distant semantically related items would signify a higher degree of impairment than errors involving selection of semantically close items; choosing unrelated distractors would suggest the most severe semantic impairment.

Cole-Virtue and Nickels (2004b) investigated the proposed relationships between WPM test items. Non-aphasic student participants completed ratings of semantic and visual similarity between distractor items and their target pairs. Although the proposed gradation of semantic similarity between target and close/distant/unrelated items was supported, inconsistencies with visual similarity were found. Visual similarity between target items and non-visually related distractors was not found to be constant. Furthermore half of the close semantic distractors were chosen on the basis of semantic and visual similarity, however the non-visually similar items in this subset were still rated as more visually similar than distant and unrelated distractors. Moreover, within the close semantic distractor subset, visually similar semantic distractors were rated more semantically similar then the non-visually similar distractors, therefore errors within the visual-semantic category cannot be assumed to be due to visual-perceptual impairment. A separate group of non-aphasic participants made judgements about the relationship between each close semantic distractor and target item. The proposed shared superordinate category relationship between all targets and their close-semantic distractor (i.e. from the same category) was also not found to be valid, with 22% of pairs regarded as possessing associative relationships instead (i.e. things that go together but not from the same semantic category) (Cole-Virtue & Nickels, 2004b).

Cole-Virtue and Nickels (2004b) also assessed the psycholinguistic properties of stimuli, and found association (i.e. lexical relationship or entity co-occurrence in the absence of semantic similarity) between items was not controlled for between targets and close or distant semantic distractors, therefore contributing a further variable which may affect WPM responses. Frequency between targets and close semantic distractors was found to be matched. To address the variability found, the authors proposed a matched subset of stimuli from the WPM test for clinicians to assess the effects in individual variables more reliably.

In WPV tasks individuals are presented with a written or spoken word and a picture and are required to indicate, via a yes or no response, whether they are the same. The written word will either match the picture or be semantically related. No published versions of word to picture verification tests are available and there has been some limited use reported with PWA (Breese & Hillis, 2004; Howard & Franklin, 1988; Howard & Gatehouse, 2006; Howard &

Orchard-Lisle, 1984; Morris & Franklin, 2012; Rapp & Caramazza, 2002). Word to picture verification tasks are discussed in more detail in section 3.1.2.

In synonym judgement tasks individuals assess the meaning relations between two or more written or spoken words (PALPA; Kay et al., 1992). Auditory and written subtests of synonym judgement are published within the PALPA. Individuals are presented with two words and are required to reflect on whether they have similar meaning; within the test half of the words are similar in meaning and half are not, and half are of low imageability and half are of high imageability (Nickels & Cole-Virtue, 2004). Although this and other subtests have received criticism, as overall 23% of PALPA tasks do not have normative data (Wertz, 1996), Nickels and Cole-Virtue (2004) provide some control data for four subtests including synonym judgement, noting control variation within their findings.

In lexical semantic association tasks, such as the Pyramids and Palm Trees Test (PPT: Howard & Patterson, 1992), individuals are required to select a written word that is most associated to the target item; in PPT this is from a choice of two. As previously discussed, it is proposed that it requires executive control of semantic knowledge to make semantic association judgements (Lambon Ralph et al., 2010). Non-verbal picture versions of semantic association tasks are also available, requiring intact object concepts to succeed at the task, i.e. the ability to retrieve conceptual knowledge about objects as represented pictorially. Examples of non-verbal conceptual tests include the PPT 3 picture version test (Howard & Patterson, 1992), the CAT 2 Semantic memory subtest (Swinburn et al., 2004), and the Camel and Cactus subtest from the Cambridge Semantic Battery (Bozeat, Lambon Ralph, Patterson, Garrard, & Hodges, 2000).

2.2.1 Limitations of existing lexical semantic tests

Explicit assessment methods of semantic processing for PWA have been introduced, alongside some of the associated limitations. In an online survey of clinicians and researchers using the PALPA (Bate et al., 2010), clinicians reported that the assessment was used for diagnosis and therapy planning, thus highlighting the need for control of psycholinguistic variables, supply of normative data and control of visual stimuli within assessment batteries to enable accurate representation of PWA ability. Within the same survey, participants expressed concern regarding the size of assessment font and the quality of picture stimuli, proposing the use of colour and photographic images to improve this confound. It is recognised within the literature that object recognition is facilitated by providing colour information, demonstrating that colour knowledge is an important part of semantic object representation (Rossion & Pourtois, 2001, 2004), and due to variation between tests of semantics, is not consistently provided.

Earlier in Chapter 1, the impact of language impairment on cognitive task performance was introduced. Furthermore, the additional cognitive skill requirements for successful performance on lexical semantic assessment are important to consider. As with all explicit assessment of semantics and cognition, additional cognitive skills are required other than those that are the focus of testing, including sustained attention, selective attention, phonological or semantic short term memory, visual-perceptual skills, inhibition of distractor stimuli, self-monitoring and self-correction. These task requirements will be explored in further detail in section 3.1. An individual with aphasia with intact semantic processing may perform poorly on a semantic test due to other additional cognitive difficulty which may not be identified by the assessor. Ultimately this could lead to incorrect diagnosis and subsequently inappropriate intervention choice. The fact that explicit tests of lexical semantics require the recruitment of a range of additional cognitive functions, all of which may well be impaired post-stroke, means that test performance is arguably reflecting the lexical semantic impairment plus impairments to attention, memory and executive function. Hence a test score is only interpretable once retained function in all these domains is clarified. Although some of the cognitive requirements of semantic tasks cannot be eradicated entirely, for example the need for sustained attention, awareness of non-linguistic task requirements in language tasks should help to prompt clinicians to be aware of these additional factors and screen clients for these prerequisite skills prior to language assessment (Ivanova & Hallowell, 2013). Where present, non-linguistic deficits can be identified as additional factors potentially contributing to outcomes on assessments of semantics, in addition to the factor of explicit versus implicit demonstration of knowledge.

Alternative methods of testing lexical semantics will be the centre of the remainder of the literature review. Whilst consideration has been given to the lack of standardisation and control of psycholinguistic variables and visual stimuli in commonly used assessments, the forward focus of Chapter 2 will be the consideration of alternatives to explicit testing methods, through discussion of implicit methods of testing, notably semantic priming.

2.3 Implicit methods of semantic assessment

There is a large amount of evidence from cognitive neuroscience showing that neurologically impaired and unimpaired individuals can present with intact knowledge that cannot be consciously recalled or demonstrated using explicit methods, but can be revealed through other behaviours such as speeded or more accurate responses in priming tasks (Eysenck & Keane, 2015). Priming is a phenomenon that results in improved speed or accuracy of response to a target if the same or a similar stimulus has been experienced previously (Tulving & Schacter, 1990). A vast literature exists which supports claims of priming of knowledge via implicit tasks, despite a lack of explicit recall, in both neurologically unimpaired participants (e.g. Tulving, Schacter, & Stark, 1982; Schacter, Badgaiyan, & Alpert, 1999; see Roediger, 1990 for a review), and neurologically impaired populations, such as those with amnesia (e.g. Cermak, Talbot, Chandler, & Wolbarst, 1985; Jacoby & Witherspoon, 1982) individuals with blindsight (e.g. Pöppel, Held, & Frost, 1973), and those with unilateral neglect (e.g. Marshall & Halligan, 1988; Berti & Rizzolatti, 1992), suggesting that the particular knowledge targeted is intact yet inaccessible via conscious recall.

Neuroimaging studies have highlighted that the broad neurological pattern observed in priming equates to reduced activation in specific brain regions in response to repeated presentation of stimuli, which has been termed repetition suppression (Horner & Henson, 2008). It is proposed that if stimuli are viewed repeatedly, associations form between the stimulus and subsequent response, therefore processing occurs more efficiently on subsequent exposures with improved synchronicity of neuronal firing (Gotts, Chow, & Martin, 2012), as various stages of processing required to select the response in the first exposure can be bypassed (Horner & Henson, 2008). The area of the brain displaying repetition suppression is dependent on the type of priming that is occurring, for example, the two main subtypes of priming, perceptual and conceptual priming (Eysenck & Keane, 2015). Perceptual priming occurs when repeated stimulus presentation results in facilitated processing of its perceptual features (Eysenck & Keane, 2015), it is modality specific and does not involve semantic processing (Blaxton, 1989). For example, it is easier to identify a degraded stimulus if recently experienced, such as in word stem completion tests; these largely involve perceptual processing, where participants are provided with a list of words to study (for example, including the word BOOK), and then a second list of word beginnings that require completion (for example, BOO), half of which will have appeared in the studied list in a completed form. When completing the part words to produce a whole word participants are more likely to produce words that they had seen in the original list (i.e. book as opposed to boot) (Graf & Schacter, 1985). This is known as repetition priming, whereby the processing of a specific stimulus is facilitated by its repeated presentation (for examples of early repetition priming studies see Forster & Davies, 1984, and Scarborough, Cortese, & Scarborough, 1977). This reflects implicit or non-declarative learning in which individuals are unable to explicitly recognise or consciously recall what has been learnt via repetition priming (Forster & Davies, 1984), or that the learning has even occurred (Knowlton & Foerde, 2008). In contrast, conceptual priming is not modality specific, occurring when repeated presentation of a stimulus facilitates processing of its meaning, for example, a decision regarding the living or non-living status of an object will made be faster if recently seen (Eysenck & Keane, 2015; Schacter & Buckner, 1998).

Different brain regions are associated with perceptual and conceptual priming. In visual-perceptual priming, reduced activation is apparent in the extrastriate visual cortex, however in conceptual priming reduced activation is apparent in the left inferior prefrontal cortex and left inferior temporal cortex. These regions are associated with activation in relation to semantic processing (Buckner, Koutstaal, Schacter, & Rose, 2000; Thompson-Shill, D'Esposito, & Kan, 1999; Wagner, Koutstaal, Maril, Schacter, & Buckner, 2000).

Although a range of methodologies is used in semantic priming, the basic paradigm is that an individual’s response to a target stimulus is measured when the target is preceded by a semantically related stimulus, known as a prime, and compared to when preceded by a semantically unrelated stimulus (McNamara, 2005). The main finding across a range of studies is of faster and more accurate responses in the related condition (McNamara & Holbrook, 2003; Meyer & Schvaneveldt, 1971; Neely, 1991). For example, the word *peach* would typically be responded to faster in a task if preceded by the word *cherry* than if preceded by the word *guitar*. Importantly, the task is viewed as implicit, as the participant is not consciously aware of the relationship between test stimuli, and not making conscious decisions about word meaning.

In the first influential semantic priming study with unimpaired participants (Meyer & Schvaneveldt, 1971), students were asked to decide if simultaneously presented pairs of written stimuli were both words, or formed a word and a nonword pair. Some of the word pairs were semantically related and some were unrelated. Meyer and Schvaneveldt (1971) found that lexical decisions were made faster for the second word when the word pairs were semantically related. They proposed that semantic priming is an indicator of how concepts are organised in semantic memory, with semantic relatedness potentially being represented by closeness in semantic space (Plaut, 1995).

The lexical decision task has since formed the basis for numerous semantic priming investigations. In a typical lexical decision semantic priming task, involving word and nonword stimuli, participants are presented with pairs of written prime-target stimuli on a computer. They are required to read the prime and subsequently make a lexical decision as to whether the target is a real word or nonword by pressing a button or computer key. When the prime-target pairs are both real words, some will be related partners (for example *daisy-poppy),* and some unrelated (for example *turtle-poppy*) (McNamara, 2005). Semantic priming methods will be discussed in more detail with control participants in section 2.4 and client groups and people with aphasia (PWA) in section 2.5.

2.4 Semantic priming processes

Models of semantic memory have been applied to semantic priming in attempts to account for the observed effect. The semantic priming phenomenon is discussed in relation to localist models, and distributed models, as introduced in section 1.3.

Localist models, where holistic units or nodes correspond to concepts, account for semantic priming in terms of automatic spreading activation from prime words to the representations of related concepts (Collins & Loftus, 1975; Neely, 1977; Posner & Snyder, 1975); meaning that a related target word would be recognised quicker in lexical decision as it would have a heightened level of activation (McNamara, 2005). An assumption applied to the Collins and Loftus (1975) model, is that the stronger the relationship between two concepts, the more connections exist between them. Items are retrieved via spread of activation, the strength of which decays with distance i.e. if two concepts are weakly related then the fewer links they will have, and the further apart they are in the network, so the longer it will take for activation to spread between them. In a semantic priming lexical decision task, if two words were related such as *cat-dog,* then activation from the prime *cat* would quickly spread to *dog* because they have many links and are close. If an unrelated prime was used such as *star*, little activation would spread to *dog* because *star-dog* are not closely related and therefore not closely linked in the network, resulting in a longer decision response latency compared to the related pair *cat-dog*. These models can also account for associative priming effects if activation is perceived as spreading between the conceptual and lexical levels (Hutchison, 2003), using the previous example, *cat* would also activate associated lexical items, such as *milk.*

Proximity-based distributed network models account for semantic priming effects in terms of the close proximity of related primes and targets in semantic space compared to unrelated pairs (e.g. Masson, 1995; Moss et al., 1994; Plaut, 1995). The semantic priming effect is considered to occur due to the similar pattern of activation between connected units for semantically related primes and targets; the system is prepared by the processing of a prime with a similar pattern of activation as a related target, therefore leading to faster processing of the target with a similar set of semantic features, or co-occurrence in the case of associative priming (Plaut & Booth, 2000). The processing of the target is faster, as a pattern of units is still activated to some extent and has not gone back to resting state, causing a faster reaction for related than unrelated prime-targets pairs (McNamara, 2005). Unlike localist network model explanations of semantic priming, after the pattern of activation for a prime is set, related concepts are simultaneously active depending on their degree of similarity, with no additional spread of activation required (Plaut, 1995).

2.4.1 Does semantic priming reflect automatic processes?

The debate as to whether semantic priming effects reflect automatic spreading-activation processes in which semantic context facilitates word recognition, or if strategic processes are involved, has received considerable critical attention (Becker, 1982). For tasks to be considered implicit, explicit decisions or awareness about the relationships between the prime and target pairs should not occur. Conscious strategies thought to impact on the automaticity of semantic processing and therefore affecting the validity of the task as an implicit measure include, i) expectancy generation and ii) post-lexical checking (de Groot, 1984).

Expectancy strategies are thought to be used when participants become aware that targets may be semantically related to primes and thus potentially generate potential candidates prior to exposure which would exaggerate a priming effect (Lucas, 2001). Post-lexical checking (also known as semantic matching) occurs when participants consciously detect prime-target relationships and refer back to the prime from the target to identify a semantic relation prior to decision (Neely, 1976; Posner & Synder, 1990; Shelton & Martin, 1992). This applies to lexical decision tasks in which participants may develop bias towards a yes/real word response if they are aware of a semantic relationship or a no/nonword response if there is no clear relationship (Neely, 1976, 1977, de Groot et al., 1982), therefore resulting in faster response latencies for words in the related condition.

2.4.1.1 Methodological considerations to reduce conscious processes

Various methodological adaptations have been found to reduce or eliminate strategic effects that contaminate the semantic priming effect. One such method is to use a continuous list paradigm. Typically, stimuli presentation in semantic priming lexical decision tasks occurs in pairs, where participants are presented firstly with a prime that they do not respond to and secondly with a target about which they make a lexical decision (for examples see Carter, Hough, Stuart, & Rastatter, 2011; Ferrand & New, 2003). In a continuous list paradigm, individuals respond with lexical decisions to all stimuli in the experiment rather than only the target, with the assumption that related pairings are therefore less obvious to participants. Reducing conscious awareness of prime-target relations through continuous list presentation of stimuli is proposed to tap automatic rather than strategic processing (Moss et al., 1995; Shelton & Martin, 1992; de Mornay Davis, 1998).

Secondly, consideration has been given to the inter-stimulus interval (ISI), the time gap between prime and target presentation, or stimulus onset asynchrony (SOA), the time between the onset of the prime and the onset of the target presentation. Using short timings of under 300ms can reduce the time-frame of opportunity for strategic processing (Hutchison, Neely, & Johnson, 2001; Perea & Rosa, 2002). When long SOAs are used inhibition effects are found, meaning that response latencies are slowed for targets preceded by an unrelated prime compared to a neutral prime such as (xxxx or the word 'BLANK') due to the time spent applying the proposed conscious checking strategies (Shelton & Martin, 1992).

Direct comparison between semantic priming studies can prove difficult as some use ISIs as the timing variable whilst others use SOAs. In an attempt to address this methodological variation timings can be categorised into short or long delays (Carter et al., 2011). When attempting to compare studies that have used different ISI or SOA timings, often there is between-study variation in other methodological decisions, such as modality, and populations tested such as controls versus neurologically impaired groups or young versus elderly groups, again making comparisons on one variable difficult to achieve. Significant variation can be seen between studies with similar participant groups, for example Ferrand and New (2003) used SOAs of 100-, 250- and 500ms in a written paired lexical decision task with university students, whereas Carter et al. (2011) used ISIs of 0- and 400ms in written and cross-modal lexical decision tasks with undergraduate students. Semantic priming effects of SOA and ISI in different client populations will be described in more detail in section 2.5.3.

Thirdly, if there is a high proportion of related stimuli in a word list, strategic processing is more likely to occur (Neely, Keefe & Ross, 1989). Priming effects in lexical decision tasks have been shown to increase as the relatedness proportion increases (de Groot, 1984). This is also related to the proportion of nonwords in an experiment, as the fewer nonwords present, the more likely that responses will be biased toward a real-word decision, therefore enhancing priming effects (Neely et al., 1989). It is recommended that use of pseudo-words, i.e. pronounceable nonwords, as opposed to unpronounceable nonwords will also reduce strategic processing (Neely, 1976, 1977; Posner & Sydner, 1975). Some studies include a neutral prime such as the word 'BLANK' so that inhibitory effects, i.e. the difference between neutral and unrelated prime conditions, and facilitatory effects, i.e. the difference between related and neutral conditions, can be monitored (de Groot, 1984).

A vast literature exists concerning the use of masked priming. Masks (e.g. ****) appear so briefly prior to prime presentation, after prime presentation, or in both positions, that participants have no or limited awareness of them. This is an additional factor known to reduce awareness of the prime (Forster & Davis, 1984, 1991; Forster, Mohan, & Hector, 2003) and therefore reduce strategic processing.

Different methodological choices in variables affecting automatic and strategic processing may have contributed to the mixed results in the semantic priming literature, such as task, continuous list delivery or paired presentation of primes and targets, the time between prime and target onset and the proportion of related and unrelated targets in stimulus lists (Lucas, 2001). Although these factors should be considered in the experimental design, it is acknowledged that selection of controlled, appropriate materials is time-consuming and difficult to achieve (Tabossi, 1996) and despite this level of stimuli control, variability between and within subjects is high. Further design choices in semantic priming methodology will now be discussed.

2.4.2 Experimental methodology and design

The two main behavioural tasks used in semantic priming are lexical decision and naming tasks, with lexical decision used more commonly (McNamara, 2005). In semantic priming tasks there is a need for items in related and unrelated conditions to be counterbalanced for comparison and also for psycholinguistic variables affecting processing, such as lexical frequency, to be controlled. Depending on the task and experimental aims, stimulus modality may also vary, and include spoken words, written words and/or pictures. The grammatical class of words used can also be constrained, for example using nouns or verbs. Primes and targets may also be related in different ways, for example they may be paired based on semantically related (*cat-dog*) or associated (*bone-dog*) relationships. Association arises when words co-occur in written or spoken contexts or physically co-occur as entities in the world, and this may be independent of semantic relationship (Lin & Murphy, 2001). Consider the hot beverages *tea* and *coffee*; they are semantically related category coordinates that share features but are also highly associated as they frequently co-occur in linguistic and real-world contexts. Instead consider *coffee* and *spoon*; they are associated as they frequently co-occur in the same context, however are not from the same taxonomic category and do not have similar meaning. Lexical semantic association is taken as an indication of word use (Ferrand & New, 2003) and ratings are typically derived from word association tasks (Postman & Keppel, 1970) i.e. what is the first word someone thinks of when given a target word within normative association databases. The following sections consider these variables.

2.4.2.1 Counterbalancing of materials and control of psycholinguistic variables

To compare performance across the two conditions of related and unrelated prime-target pairs, ideally the same words would be used in both conditions. This is a confound in semantic priming experiments however, because repetition of items could cause interactions with semantic relations (McNamara, 2005) as increased priming effects have been noted when items are repeated within tests (Durgunoglu, 1988). To address this problem materials can be counterbalanced across experimental conditions and participants. Two groups may undertake the task, group 1 seeing half of the primes and targets in the related condition, and half in the unrelated condition and group 2 seeing the primes and targets in the opposite related or unrelated conditions. This allows for one presentation of each prime and target stimulus per person rather than individuals having repeated exposure in both a related and an unrelated condition. Results can then be compared by-participant, where the group mean related and unrelated response latencies can be compared, or at the by-item level, where mean response latencies to targets in the related and unrelated conditions can be compared.
Counterbalancing is often preferred to designing two separate word lists in which different target stimuli are matched on the experimenter's chosen variables such as frequency, imageability and word length (McNamara, 2005), as the lists may inadvertently differ on another unexamined variable.

When it is not possible to counterbalance two lists of stimuli due to design constraints, psycholinguistic variables are controlled between primes and targets to ensure that the semantic relationship between the prime and target is responsible for the semantic priming effect and no other confounds could be contributing. These include psycholinguistic properties such as semantic relatedness (McNamara, 2005), type of semantic relations (e.g. coordinates or instrument relations such as *mop-floor*), association strength (Moss et al., 1995), frequency (Becker, 1979), length (Silkes & Rogers, 2010) and visual-perceptual similarity. When there are many factors to consider in the design of priming word lists, it is not always possible to control for all psycholinguistic properties such as phonological or orthographic neighbourhood density, age of acquisition, or familiarity (Silkes & Rogers, 2010).

2.4.2.2 Stimulus modality

A further variable that can impact on the semantic priming effect is stimulus modality; lexical decision semantic priming tasks typically involve written stimuli. Within-modality prime and targets can be utilised, where primes and targets would be presented in the same modality, such as both auditory or both written (for examples of auditory stimuli see Moss et al., 1995; Nation & Snowling, 1999; Ostrin & Tyler, 1993; and for written stimuli see Fischler, 1977; Milberg & Blumstein, 1981; Perea & Rosa, 2002). In cross-modality study designs the prime and target modality are different, for example where the prime is presented auditorily and the target is presented orthographically (for examples see Balota, Watson, Duchek, & Ferraro, 1999; Carter et al., 2011; Moss, McCormick & Tyler 1997).

Holcomb and Neville (1990) used Event Related Potentials (ERPs) as a measure to compare semantic priming in auditory and visual modalities. They found electrophysiological and behavioural evidence of priming in both modalities suggesting that comparable mechanisms underlie priming in both. Differences however, existed in the time course of activation: in the auditory condition ERP priming effects were significantly greater, began sooner and lasted for a longer period of time compared to the written condition. It is possible that word recognition for auditory stimuli may occur earlier than written stimuli if they are recognised before the whole word is produced (Marslen-Wilson & Tyler, 1980).

The hypothesis that the processing required to activate meaning for spoken and written words may differ for each modality has been further investigated. A study comparing the time course of visual and auditory semantic processing by manipulating the SOA in ERP priming reported several differences between modalities (Anderson & Holcomb, 1995). For written stimuli, behavioural and ERP findings of the N400 effect (a negative change in potential after stimulus-onset related to semantic processing [McNamara, 2005]) were evident when using both short and long SOAs, however for auditory stimuli large priming effects occurred later (800ms) with smaller and less consistent findings below this threshold. Temporal differences in processing may account for these differences, as presentation of auditory stimuli is revealed over time and then disappears whereas with visual stimuli whole words are available for processing from the initial point of presentation. It is proposed that at shorter SOAs acoustic information is not processed fully in time to prime target words. It has however been argued that an isolation point exists at which auditory stimuli are recognised before a whole word is heard (Tyler & Wessels, 1984), which would be followed by a recognition point 100-150ms later when certainty of the word recognition increases to over 80% (Moss et al., 1997).

It is suggested that there are larger effect estimates for auditory primes compared to written primes, potentially due to “preferred access” (Hutchison, 2003, p.806) to semantics or the possibility that auditory primes leave an echoic trace which could cause participants to make a conscious decision based on perceived relatedness of the items. Lexical co-occurrence of prime-target pairs may influence the priming effect, and would typically happen within the same modality (McKoon & Ratcliff, 1992; Shelton & Martin, 1992), therefore in cross-modal priming this potential effect may be reduced. Priming across modalities has been demonstrated however, suggesting that semantic priming effects are amodal and stem from activation of central semantic representations (Balota et al., 1999). The previously mentioned associative boost - that semantically related pairs that are also associated result in larger priming than pairs that are not associated - has been reported when stimuli are presented orthographically (Lucas, 2000; Hutchison, 2003). One review (Hutchison, 2003) reported that priming has been found to occur for auditorily or visually presented stimuli sharing a semantic relation (in the absence of association) in both paired and continuous list lexical decision tasks. However, differences in priming for different prime-target word relationships have been reported, for example that semantic category priming occurs in studies with auditory but not visual presentation of words (Moss et al., 1995).

Debate also exists regarding whether verbal (i.e. word) and non-verbal (i.e. picture) input have differential access to semantics. Some argue that pictures have privileged access to semantics whereas words have privileged access to the lexicon (Glaser & Glaser, 1989; Dual coding Theory see: Paivio, 1986), while others propose similar access to semantics for both (Amrhein, McDaniel, & Waddill, 2002). Occasionally picture stimuli have acted as primes in naming tasks revealing small priming effects (Carr McCauley, Sperber, & Parmelee, 1982; Sperber, McCauley, Ragain, & Weil, 1979). In these studies however a limited number of pictures were used multiple times, with varied controlling of SOAs and naming of the target and then the prime. The use of pictures as masked primes with written targets in a naming task has also been investigated (Hines, 1993). Neural correlates of picture to word and word to word semantic priming has been investigated using fMRI methodology (Kircher, Sass, Sachs, & Krach, 2009), with similar priming effects found at both a behavioural and neural level for intra-modal and inter-modal priming. Both picture and word priming resulted in deactivation in the bilateral fronto-temporal regions, areas that are involved in semantic and associative processing independent of modality. The authors propose that initial neural activation is modality specific but that the different modality processing routes converge and rely on an amodal common neural network for semantic processing.

Dorjee, Devenney, & Thierry (2010) carried out an electrophysiological investigation of repetition priming within and across modality of written, auditory, pictorial and environmental sound stimuli. Neurologically intact participants were asked to respond if two identical stimuli occurred in immediate succession. The P3 wave amplitudes, which are thought to reflect more automatic semantic access in comparison to the N400 wave (Hill, Strube, Roesch-Ely, & Weisbrod, 2002; Hill, Ott, & Weisbrod, 2005), were large in the inter-modal conditions but also in the word to picture and picture to word prime-target pairs. Interestingly however, they found larger effects for written primes compared to pictures even when the target was in a different modality i.e. written to picture presentation. It was proposed therefore that written words result in more efficient semantic access and retrieval than pictures.

2.4.2.3 Perceptual priming

Perceptual priming based on shared physical attributes of the objects depicted in the words (e.g. colour or shape), can be categorised as a subtype of semantic priming, as physical features of a word's referent are likely to form part of the lexical semantic representation. Evidence for perceptual priming in both lexical decision and production tasks is limited. Pecher, Zeelenberg and Raaijmakers (1998) failed to find priming effects for perceptually related words e.g. does *pizza* prime *coin*, or does *glue* prime *honey*, apart from conditions where prior to the task participants made explicit decisions about words’ referents’ physical features. For example, in a read-aloud task a significant perceptual priming effect was found but only when stimuli had been previously activated in a categorisation task that required perceptual decisions as to whether the items were oblong in shape or had a flat surface. In a lexical decision task priming was only found if it was preceded by the perceptual categorisation task and if all associated items were removed from the word list - seemingly due to elimination of the relatedness checking strategy said to be employed by participants if consciously aware of stimuli associations.

In an auditory lexical decision task Kellenbach, Wijers and Mulder (2000) did not demonstrate perceptual priming effects in reaction time or accuracy data but revealed a robust electrophysiological response in an ERP task. A reduction in amplitude around 400ms after stimulus-onset (the N400 effect) has been shown to occur with the processing of semantically related information. In a separate study however perceptual priming effects for perceptual attributes e.g. *sparkles-diamond*, and essential attributes, e.g. *mineral-diamond*, were observed at the behavioural level using a written lexical decision task, but were not present in a naming task (Lucas, 2001).

Evidence has also been cited that object manipulation knowledge forms part of semantic representations. A marginally significant priming effect has been demonstrated in an auditory lexical decision task where objects were related by manipulation similarities (e.g. *piano-typewriter*) compared to unrelated objects (e.g. *blanket-typewriter*) (Myung, Blumstein, & Sedivy, 2006). In the Lucas (2001) and Myung et al. (2006) studies, word sets were selected using numerical relatedness ratings collected in preliminary experiments. On inspection however, some of the suggested relations again seem tenuous, such as manipulation similarity (for example *shoehorn-spade*; Myung et al., 2006) and perceptual characteristics (for example *bald-eagle*; or *oil* with the features *black* and *flammable*; Lucas, 2001). As will be discussed in the following section 2.4.2.4, the prime-target relationships can vary and categorisation is rarely binary or unidimensional.

2.4.2.4 Prime - target relationship

Within the literature there is a lack of consensus regarding the type of prime-target relationships that result in the semantic priming effect. Originally it was proposed that the semantic priming effect was due to the semantic relationship between prime-target pairs, indicative of an overlap in features or similarity in meaning, for example the semantic coordinates *robin-wren*. However, the distinction between semantic versus associated prime-target pairs is often neglected in semantic priming studies. In the original Meyer and Schvaneveldt (1971) semantic priming study word pairs were not only semantically related, but also highly associated (e.g. *bread-butter*, *doctor-nurse*), and there are other examples of studies where the associative relationship between stimuli lack control (for example, de Groot, 1984).

As a result there here has been debate regarding whether a semantic priming effect can occur solely from the semantic relation between words (Fischler, 1977) or if the effect could be due to association (Lupker, 1984), or a combined effect of the two. One of the first studies to attempt to tease apart semantic and associative priming found priming effects for both types of relationship using a written lexical decision task. (Fischler, 1977). It is postulated that an “associative boost” is often provided (Lucas, 2000, p. 619; for a review see Hutchison, 2003) in addition to the influence of semantics. Correlation between word associations and co-occurrence in language corpora has been found (Spence & Owens, 1990). It is suggested that automatic priming can occur independently at the lexical form level as a result of association (Shelton & Martin, 1992). Form-level connections between associated words could strengthen due to repeated co-occurrence in use (Moss et al., 1995; e.g. *needle* and *thread*, Lucas, 2000), and therefore contribute to a perceived ‘semantic’ priming effect (Fischler, 1977). Between-study comparison of the separate contributions of semantic or associative priming is often difficult however due to the lack of control or explicit consideration of relationship between experimental stimuli, and differences in task methodology.

The inconsistent patterns of semantic priming between experiments may also be related to the type of semantic relationship being examined (McRae & Boisvert, 1998; Moss et al., 1995). Few studies have directly assessed semantic priming of prime-target pairs that are antonyms (e.g. *day-night*) and synonyms (e.g. *boat-ship*), however small semantic priming effects have been found in those that have (Hodgson, 1991; McKoon & Ratcliff, 1995; Perea & Gotor, 1996; Perea & Rosa, 2002), potentially due to the high level of featural overlap. The evidence for priming effects from non-associated semantic coordinates (e.g. *pigeon-chicken*) is weak (Hutchison, 2003). Priming involving different categories of semantic relations while controlling for association strength has been investigated with control participants (Moss et al., 1995), including category coordinates (e.g. *boat-ship*), functional properties of instrument relations, in that the function of one item is to perform an action on the other (e.g. *shampoo-hair*) and script relations (e.g. *pub-beer*) where items are part of the same script or schema (see Rumelhart, Smolensky, McClelland, & Hinton, 1986; Schank & Abelson, 1977). Moss et al. (1995) proposed that despite being typically regarded as possessing associative relationships, instrument and script functional relationships between concepts form a part of the semantic representations. A priming effect was demonstrated for all relationship types, with and without association, in one semantic priming lexical decision task with auditory paired presentation of prime-target pairs. In a second experiment using an auditory continuous lexical decision task the priming effects were reduced, potentially indicating that strategic influences were present in the first experiment. There was also evidence of an increased priming effect for words that were both semantically and associatively related, supporting the associative boost proposal. A third experiment was completed using written continuous presentation lexical decision in which different patterns were found, including priming of instrument targets independent of association, priming for coordinates only when associated, and no priming for script relations. Moss et al. (1995) propose that the single word list presentation used in the third experiment is the only design to reflect true automatic semantic priming (Shelton & Martin, 1992), as demonstrated for instrument relationships only. However, it is acknowledged this method often produces inconsistent results and small priming effects, therefore the results found may not reflect the difference between strategic and automatic processing, instead representing the different time courses of activation for the different word relationship types, i.e. instrument relationships may have faster activation speeds than coordinate or script relations (Moss et al., 1995).

Differences in the contribution of association to the semantic priming effect are also present between research studies with different task designs. In a lexical decision task using a continuous list presentation, Shelton and Martin (1992) revealed priming only for associated words and not for words with a purely semantic relationship. Ferrand and New (2003) demonstrated independent effects of both semantic and associative priming in a paired lexical decision task, while others have demonstrated semantic priming effects in both paired and continuous lexical decision (McRae & Boisvert, 1998) and picture naming (Thompson-Schill, Kurtz, & Gabrieli, 1998), independent of association.

In a review paper Hutchison (2003) reports that the evidence for semantic priming in category coordinate pairs is limited, with stronger evidence for non-associated functionally related items, including instrument associations such as *grill-toast*, and script relations e.g. *party-music*. Evidence is cited for semantic priming due to featural overlap and for ‘pure’ associative priming. In the Lucas (2000) meta-analytic review paper, it was concluded that semantic priming can occur without association, particularly for coordinate pairs. Studies included in the meta-analysis used stimuli of moderate to high association and methodologies that enable strategic rather than automatic processing, which may account for the contrary findings of the two reviews.

‘Pure’ semantic or associative priming is hard for researchers to achieve when designing semantic priming word lists. To gather evidence of an independent semantic priming effect, pairs of words would ideally be semantically similar but with weak or no association (e.g. *fork-spoon*). However, difficulty arises as semantically related items are often also associated (e.g. *cat-mouse*). Conversely, in investigation of association priming, associated words with no or low semantic similarity norms would ideally be paired (e.g. *sausage-barbeque*). However, words with high association are often also semantically related, therefore in designing word lists for priming experiments examining pure associative priming effects, researchers are often limited to using select stimuli pairs with only weak or moderate association (Hutchison, 2003).

Attempts have been made to further distinguish between semantically related and associated stimuli relationships. Words or objects sharing featural overlap within categorical or taxonomic relationships, such as vegetables, have been described as having *similarity* relations whereas *thematic* relations arise from those associated via situations or co-occurrence in events

(Mirman & Graziano, 2012b). Take the example of a trip to the cinema; objects such as popcorn and tickets may be thematically related due to both being associated with the event. Thematic relations are referred to as possessing “complementary features” as opposed to the shared features of similar objects from the same category (Mirman & Graziano, 2012a, p.1990). Lin and Murphy (2001) provide examples of associative relations such as, spatial (e.g. a roof is on top of a house); functional (e.g. a fork is used to eat spaghetti); and temporal (e.g. bills come after eating a meal out). Different researchers have used different classification systems however, for example Hutchison describes 14 types of associative relationships, including script relations (e.g. *orchard-apple*) and instrument relations (e.g. *broom-floor*).

Individual differences have been found in processing of similar versus thematic relations in neurologically unimpaired participants. In explicit similarity judgement tasks it has been demonstrated that some participants match similar stimuli to target words that share category relations, whereas others consistently choose stimuli that match in thematic relation (Simmons & Estes, 2008). Eye-tracking methods have demonstrated that these individual differences remain across tasks with different requirements; in spoken word comprehension tasks where semantic stimuli act as distractors and are not explicitly considered in the task response, individual control participants fixate differently, with some focusing more on thematic relations, others on taxonomic relations (Mirman & Graziano, 2012b).

Additional research posits distinct neuroanatomical regions as the basis for differences between thematic versus categorical relation processing (Schwartz et al, 2011). There is a comprehensive amount of knowledge demonstrating the role of the anterior temporal lobe (ATL) in the storage and processing of taxonomic semantic knowledge (see Patterson, Nestor, & Rogers, 2007 for a review), which has implications for studies involving participants with neurological damage. For example, in naming studies with PWA, it has been identified that the ATL may play a role in object identification through processing of visual features, which could account for the predominance of taxonomic naming errors over thematic naming errors. Although less is known about the neurological basis of processing of thematic relations, it is believed that the left temporo-parietal cortex (TPC) may be a further key semantic hub responsible for processing events and extracting role relations in PWA (Schwartz et al, 2011; Mirman & Graziano, 2012a).

Due to the uncertainty surrounding the role of prime-pair semantic relationships in semantic priming, and the expanding evidence base in support of the distinct processing of taxonomic versus thematically related words, in the current study experimental stimuli were selected to enable consideration of the potentially divergent effects of the two word categories. Hereafter, for ease of reference the terms used to distinguish between the two different types of word relations will be *semantically similar* and *associated.*

2.5 Semantic priming in neuropsychological research

Semantic priming has been used to investigate language impairment and explore the integrity of semantic processing in individuals with varied aetiologies, for example: Williams Syndrome (Tyler et al., 1997); specific language impairment (Nation & Snowling, 1999; Pizzoli & Schelstraete, 2011); schizophrenia (for a systematic review see Pomarol-Clotet, Oh, Laws, & McKenna, 2008); acquired dyslexia (Crutch & Warrington, 2007); semantic dementia (Moss, Tyler, Hodges, & Patterson, 1998; Nakamura, Nakanishi, Hamanaka, Nakaaki, & Yoshida, 2000); Alzheimer's type dementia (Balota et al., 1999; Chertkow & Bub, 1990) and aphasia (for a review see Del Toro, 2000). Those most relevant to speech and language therapy research will be considered, including children with poor comprehension, people with Alzheimer's disease and semantic dementia, and people with aphasia (PWA).

2.5.1 Semantic priming with children

Using an auditory continuous lexical decision task, Nation and Snowling (1999) tested 22 university students, 16 children with normal reading ability and 16 children with poor comprehension, to investigate integrity of semantic knowledge. A subset of stimuli was included from a previous priming study (Moss et al., 1995) that has been rated by adults as very familiar to children aged 10; half of these were reported to be related by category (e.g. *comb-brush*), half by function (*hammer-nail*), then within each category half of the prime-target pairs had weak association, half had strong association. Due to these matching constraints the authors report that it was not possible to match the four word sets by frequency. Priming effects were demonstrated in all participant groups, providing evidence that words were automatically semantically processed when heard. The children with poor comprehension demonstrated significant semantic priming effects, despite demonstrating poor performance on explicit measures (Nation & Snowling, 1998). The adult control participants demonstrated priming for categorically and functionally related prime targets pairs, whether associated or not. The group of children with poor comprehension however only demonstrated priming effects for categorically related words when they were associated. It is suggested that this may be a reflection of lexical co-occurrence, i.e. form-based priming effects, as they may not have developed the categorical semantic knowledge required for semantic priming to occur. More recently it has been proposed that larger priming effects seen in a semantic priming study in children with Specific Language Impairment compared to controls may be due to over-activity in the lexical-semantic system to compensate for impaired grammatical processing (Pizzioli & Schelstraete, 2011).

2.5.2 Semantic priming in semantic dementia and Alzheimer's-type dementia

Semantic dementia (SD) is a term used to describe a neurological degenerative disorder of semantic memory resulting in loss of expressive and receptive vocabulary and object knowledge (Hodges et al., 1992). Most other cognitive functioning remains preserved for the majority of the disease progression, including intact functioning of episodic memory, short-term memory, visuo-spatial processing and problem solving (Patterson, Nestor & Rogers, 2007).

Through comparison of an implicit written paired semantic priming task and an explicit statement verification task, Tyler and Moss (1998) illustrated the gradual deterioration in different types of semantic knowledge across both tasks in a person with semantic dementia, AM. Unlike controls, AM did not show semantic priming for category labels (*fox-animal*) or co-ordinates *(fox-dog*) at any of the three testing points over an 18 month period. Initially a semantic priming effect was found for perceptually (*fox-red*) and functionally (*fox-sly*) related prime-target pairs, however these effects disappeared at retesting 11 months later for perceptual attributes and by the third testing for functional relationships. The pattern of semantic deterioration seen in AM does not support hierarchical models of conceptual knowledge, where superordinate categories would be the most preserved; in AM semantic priming effects demonstrated that knowledge for semantic features was preserved for longer. Deterioration of functioning on explicit semantic tests has been shown to follow a similar pattern of decline over time, supporting the claim that in semantic dementia, unlike semantic aphasia, knowledge is degraded rather than being inaccessible (Jefferies & Lambon Ralph, 2006).

More recent studies have failed to find a semantic priming effect for functional attributes in people with semantic dementia (Laisney, Giffard, Belliard, de La Sayette, Desgranges, & Eustache, 2011; Rogers & Friedman, 2008), however the heterogeneity of classification of what constitutes a functional relationship within and between studies has been raised. Within the Tyler and Moss (1998) study examples of functional relationships include *desk-work*, *crocodile-river*, and *fox-sly*, which in turn includes an object to perform an action, a contextual/habitat relationship, and a relationship based on lexical association or proverbs (Merck, Jonin, Laisney, Vichard, & Belliard, 2014). In an attempt to address this problem, Merck et al. (2014) ran a written semantic priming experiment with people with semantic dementia, where prime-target relationships were more tightly controlled. Prime-target pairs were devised to be related either by visual-perceptual features (e.g., *ostrich-neck*) where one stimulus was an inseparable component of the other, or contextual relationships, (e.g., *bed-pillow*) where the two stimuli could exist independent of the other. Inverse effects were found for the control and semantic dementia groups: control participants showed priming in the visuo-perceptual condition and not the contextual condition, whereas the semantic dementia group primed for contextual pairs but not visuo-perceptual features. It is hypothesised that in control participants the semantically similar relationships show an advantage resulting in visuospatial priming, however as perceptual feature knowledge was impaired in the individuals with semantic dementia, the processing of thematic relationships demonstrated an advantage.

Alzheimer's type dementia differs to semantic dementia in that the main impairment is of episodic memory, but with some level of semantic impairment as demonstrated on tests of naming and word fluency (Chertkow, & Bub 1990; Martin & Fedio, 1983). Contradictory findings exist with regard to the performance of people with Alzheimer's disease (AD) on tests of semantic priming in comparison to control participants including reduced priming (Bushell & Martin, 1997), similar priming or hyper-priming which some propose to be a result of general cognitive slowing (Chertkow, Bub, & Seidenberg, 1989; Giffard et al., 2001, 2002; Hartman, 1991; Nebes, Brady, & Huff, 1989). It is argued that hyperpriming demonstrates intact semantic knowledge that is only accessible via implicit methods, occurring due to generalised slowing in AD. If people with AD show longer response latencies in the unrelated condition in comparison to control participants, it is proposed that hyperpriming reflects the larger decrease in response latency in the semantically related prime condition in participants with AD (Nebes, Brady & Huff, 1989). The mixed results within the literature are likely to be due to between-study methodological variation that may influence the likelihood of strategic processing, for example length of ISI, relationship between prime-target pairs and proportion of relatedness between stimuli (for a review see Giffard, Desgranges, & Eustache, 2005). For example, using a written continuous list-presentation and lexical decision task with ISI of 250ms to minimise conscious processing, Nakamura et al., (2000) reported no priming in Japanese speaking participants with semantic dementia but priming effects in control participants and those with AD, however this is not easily comparable to studies with different methodological constraints within the semantic priming experimental design.

2.5.3 Semantic priming in people with aphasia

Many types of priming have been investigated in people with aphasia (PWA) including: rhyme priming (e.g. Baum, 1997; Gordon & Baum, 1994); phonological priming (e.g. Misiurski, Blumstein, Rissman, & Berman, 2005); mediated priming (e.g. Baum, 1997; Milberg, Blumstein, & Dworetzky, 1988); repetition priming (e.g. Silkes & Rogers, 2012; Soni, Lambon Ralph, & Woollams, 2012); grammatical priming (e.g. Bates, Marangolo, Pizzamiglio, & Dick, 2001); effects of sentence contextual constraints (e.g. Baumgaetner & Tompkins, 2002); as well as semantic priming in naming tasks (e.g. Alario, Segui, & Ferrand, 2000), however the following review will focus on semantic and associative priming in input tasks.

For PWA assessment and therapeutic tasks tend to be offline or explicit in nature, requiring conscious decision-making and executive skills. Studies investigating online methods in PWA, in particular lexical semantic priming, are limited and often focus on sentence processing as opposed to single words. As discussed in Chapter 1, semantic impairment in aphasia has been predominantly accounted for by dichotomous explanations, either by loss of central stored semantic representations affecting both written and auditory modalities, or semantic access problems, which may affect both modalities or just one. Difficulties are more easily attributable to access problems if impairment is only present in one modality (Moss & Tyler, 1995), for example as in word meaning deafness where individuals present with impaired understanding when given auditory stimuli, but intact understanding of written material via the orthographic route (Franklin, 1989). Explanations are not as transparent if impairment is modality independent and apparent across input and output routes, as problems could still be accounted for by impairment of access, storage deficit, or a combination of these (Moss & Tyler, 1995) or alternatively due to the complexity of the explicit tasks used and concomitant deficits in other critical cognitive domains including attention, memory attention or executive function. Semantic priming experiments have a role here, in providing online, temporal exploration of specific skills, with fewer additional non-linguistic cognitive factors than required by explicit tasks (Howells & Cardell, 2015).

Of the semantic priming studies with PWA, lexical decision is the typically used task to assess semantic knowledge implicitly, at times in contrast to explicit semantic tasks that suggest impaired semantic knowledge. For example, one direct comparison of semantic processing abilities of PWA across implicit and explicit semantic tasks found that the PWA groups categorised as having low comprehension abilities demonstrated semantic priming in a paired auditory lexical decision task with 500ms ISI, yet demonstrated impaired performance on an explicit semantic judgement task (Chenery, Ingram, & Murdoch, 1990).

As mentioned in relation to the semantic dementia priming studies, the heterogeneity within both the PWA population itself and also in study methodologies, such as stimulus modality, timeframe and presentation, gives rise to difficulty in reaching overarching conclusions about semantic priming in aphasia. Research on the subject has been mostly restricted to reports of small numbers of clients categorised by patterns of priming in relation to aphasia syndrome classification. For example, Broca's aphasia; presenting with non-fluent speech but relatively intact comprehension (for examples see Blumstein, Milberg & Shrier, 1982; Del Toro, 2000), Wernicke's aphasia; presenting with fluent speech but impaired comprehension (for examples see Milberg & Blumstein, 1981; Milberg, Blumstein, & Dworetzky, 1987), or more broadly as fluent aphasia (Gordon & Baum, 1994; Tyler, Ostrin, Cooke, & Moss, 1995). Initially, effects of implicit semantic priming were considered alongside the pattern of people with Broca's aphasia performing better on explicit semantic assessment in comparison to individuals with Wernicke's aphasia (Goodglass & Baker, 1976; Zurif, Caramazza, Myerson, & Galvin, 1974) and it was concluded that lexical semantics were intact in Broca's aphasia (Grober, Perecman, Keller, & Brown, 1980) and impaired in Wernicke's aphasia (Yee, 2005). A recent study has attempted to break down the subgroup of fluent aphasia by examining semantic priming in people with anomic aphasia (Howells & Cardell, 2015) i.e. individuals with fluent speech, good comprehension abilities and word finding difficulties (Geschwind, 1967; Lambon Ralph, Sage, & Roberts, 2000). Individuals with anomic aphasia demonstrated a semantic priming effect via an auditory to written cross-modal pairwise paradigm. There is debate however within the literature regarding the usefulness of categorisation of aphasia syndromes (Ardila, 2010; Gordon, 1998; Marshall, 2010; McNeil & Copeland, 2011) and a lack of guidance regarding the categorisation process itself, for example in the consistent use of what constitutes the fluent and non-fluent aphasia dichotomy (Silkes & Rogers, 2012). As a result these subgroups may be limited in their ability to provide meaningful or useful comparisons with which to compare semantic priming performance in aphasia. Due to the wide variation within the literature methodology and participants, what follows is a chronological summary of the key semantic priming studies with PWA.

2.5.3.1 The development of semantic priming research in aphasia

In the early 1980s the first semantic priming studies with PWA were reported. In contrast to the originally held view that lexical semantics were impaired in Wernicke's aphasia and not in Broca's (Yee, 2005), in these initial semantic priming studies, people with Broca's aphasia showed no or reduced semantic priming effects, demonstrating impaired semantic processing, whereas people with Wernicke's aphasia demonstrated priming similar to control groups. This was first illustrated by Milberg and Blumstein (1981) in a study that included five participants with Broca's aphasia, six participants with Wernicke's aphasia, and single cases of conduction and global aphasia. Individuals were tested on a small set of coordinate pairs (*n*=10) and superordinate pairs (*n*=5) in a list presentation written lexical decision task where participants responded to all stimuli; the rationale for the continuous list presentation being that PWA could not inhibit responses to primes. However the task cannot be strictly classified as continuous list as there was an ISI of two seconds between prime and target presentation, and four seconds between response and the next prime presentation, therefore the timings may have delineated and drawn attention to pairs of word, potentially supporting strategic processing. Results showed that Broca's-global participants did not demonstrate semantic priming. Participants with Wernicke's aphasia demonstrated a semantic priming effect for both superordinate and coordinate stimuli relationships, however failed to demonstrate this knowledge on an explicit semantic judgement task using the same stimuli. There was also no correlation between priming and scores on tests of auditory word discrimination and word reading. This was given as evidence that people with Wernicke's aphasia do not have an underlying semantic impairment, but are impaired at accessing their knowledge metalinguistically.

These patterns of Broca's and Wernicke's performance were mirrored in two follow-up studies including an auditory pairwise design with 500ms ISI and eight seconds between response and next prime presentation (Blumstein et al., 1982), and a more complex triplet priming design (Milberg et al., 1987). The latter task used context to prime lexical decisions on the third word presented in an auditory triplet preceded by a semantically ambiguous second item. Four prime conditions were used: (1) coin-bank-MONEY in which the first prime and target were related to the same meaning of the second prime; (2) river-bank-MONEY in which both the first prime and target were individually related to the different meanings of the second prime; (3) desk-bank-MONEY in which only the second prime and target were related; and (4) a baseline condition where all words were unrelated and unambiguous. In control participants and the group with Wernicke's aphasia the context of the first word primed lexical decision on the third word, but this did not occur in the group with Broca's aphasia. The study has received criticism however for lack of control of potential repetition priming effects, as each participant was exposed to the each target on four occasions; when this was addressed in a later study, repetition effects were controlled the findings were not replicated (Hagoort, 1989). Further methodological limitations include the potential for strategic influences in paired lexical decision tasks, when long intervals occur between prime and target presentation, and the confound of using stimuli that are both semantically related and associated. These lines of enquiry and subsequent studies suggested that a lack of semantic priming in people with nonfluent/Broca's aphasia equates to delayed lexical activation either due to slowed automatic semantic access (Prather, Zurif, Love, & Brownell, 1997) or reduced strength in automatic lexical semantic activation (Milberg, Blumstein, Katz, Gershberg, & Brown, 1995; Milberg et al., 1987); it is acknowledged that the consequences would be similar, in that individuals show reduced ability to decode lexical semantic information in real time (Del Toro, 2000).

Ostrin and Tyler (1993) partly addressed methodological issues pertaining to the potential for strategic processing by reducing the ISI to 250ms and controlling for both semantic relatedness and association in a paired auditory lexical decision task. Intact automatic semantic processing was found in participants with Broca's aphasia when these methodological alterations were applied, which the authors cite as evidence of intact automatic access to lexical semantic knowledge in the Broca's aphasia subgroup.

Furthermore, findings of residual semantic knowledge in people with non-fluent aphasia was replicated, again using pairwise auditory semantic priming tasks (Tyler, Moss, & Jennings, 1995). Two patients with non-fluent Broca's aphasia, JG and DE, were both shown to present with a significant semantic priming effect and similar response times to control participants, suggesting automatic access to semantic information was unimpaired. There was no difference in the semantic priming effect between prime-target pairs with semantic co-ordinate or functional relationships. Although there was a trend towards an association boost for strongly associated pairs, this did not reach significance. JG and DE also presented with specific impairment of abstract compared to concrete nouns on explicit tests of spoken word to picture matching and read aloud tasks. However typical lexical decision latencies and priming for concrete *and* abstract words were demonstrated with an auditory pairwise semantic priming task (Tyler et al., 1995a). These findings suggest that conceptual representations were unimpaired and can be automatically accessed in people with Broca's aphasia. However this interpretation is met with caution by those who argue that significant priming cannot be cited as direct evidence for intact representations because priming could still be facilitated by degraded semantic representations (Rapp & Caramazza, 1993).

Implicit semantic processing in pairwise written lexical decision tasks has also been explored with PWA. Studies adapted the semantic priming task to manipulate the effects of automatic and strategic processing, through comparison of low and high relatedness proportions of prime-target pairs, and comparison of short and long SOAs. In a study with seven participants classified as having Broca's aphasia and one as having transcortical motor aphasia, Bushell (1996) reported atypical priming patterns in contrast to a control group. Control participants were tested with set parameters of 500ms for prime presentation, ISI and target presentation. To minimise error rate for PWA temporal parameters were varied; the prime and target presentation time was set at 1000ms for half of participants and 2000ms for the remaining half, with an ISI of 500ms for all, thus enabling accuracy rates of over 80%. Experiment 1 had two conditions: to maximise conscious strategic processing within the lexical decision task, the condition one word list had a high proportion of related stimuli (80%) so that participants would generate expectations regarding semantic relationship; and to minimise strategy in condition two, the relatedness proportion between stimuli was low (20%). A semantic priming effect in the high relatedness condition was observed in the control group, however in contrast the PWA showed an inhibitory effect. It is argued that this finding suggests impaired *controlled* semantic processing in PWA, due to difficulty associated with the strategy of attempted generation of a related target in the high relatedness proportion condition. These patterns were present in the low relatedness condition but did not reach a significant effect of priming, which is explained via a lack of expectancy-based strategy due to the long SOA, during which automatic semantic activation decayed. However the author notes that the fact that PWA were sensitive to the relatedness proportion as demonstrated by inhibited priming, could signal residual aspects of controlled semantic processing, but difficulty accessing that information in the circumstances.

In contrast, Hagoort (1997) found semantic priming effects for 13 people with Broca's aphasia in a paired visual lexical decision task across both short (300ms) and long SOAs (1400ms). The short SOA was used to provide conditions for reduced or absent strategic processing and increased strategic processing in the long SOA condition. As short SOAs are believed to assess automatic lexical processing, these findings are used to dispute the claim that automatic access of word meaning is impaired in Broca's aphasia (Milberg & Blumstein, 1981).

Further support for intact implicit semantic processing in people with Broca's and also Wernicke's aphasia was provided by Baum (1997) in a study of semantic, phonological and mediated priming with 10 fluent and 11 nonfluent PWA. In a paired auditory lexical decision task with an ISI of 500ms they found evidence of typical semantic priming similar to control participants in 10/11 people with nonfluent aphasia but only half of participants with fluent aphasia. It was found that those PWA who demonstrated inconsistent priming effects had the more severe comprehension deficits, providing some evidence for impaired automatic semantic activation in Wernicke’s aphasia. The semantic priming results are in contrast to earlier studies finding robust priming in Wernicke’s aphasia (e.g. Blumstein et al., 1982; Milberg & Blumstein, 1981). Baum suggested that this could be due to the relative low rate of semantically related pairs within the stimuli (6% compared to 17% in Milberg & Blumstein, 1981), as other conditions were being investigated within the experiment such as rhyme. The findings have been criticised on this basis however, as potentially the inclusion of phonologically related items may have interfered with the perceived effect (Howells & Cardell, 2015).

In addition to variations in modality, ISI and SOA in PWA semantic priming methodology, the continuous list priming paradigm has been investigated in further attempts to reduce the impact of strategic processing on performance outcomes. In a written continuous list semantic priming task, elderly control participants have shown semantic priming at an ISI of 500ms and marginally at 800ms (Stern, Prather, Swinney, & Zurif, 1991). Prather and colleagues report findings that support the hypothesis of a delay in lexical semantic activation for people with Broca’s aphasia, and a delay in deactivation for people with Wernicke’s aphasia. In PWA case studies they found two participants with Broca’s aphasia who show the same rise and fall in prime effect as control participants, but that the prime effect occurred later than for controls, at 1500ms (LD: Prather, Zurif, Stern, & Rosen, 1992; and FC: Prather, Zurif, Love, & Brownell, 1997), thus supporting the view of slowed automatic lexical activation in this patient group. Using the written list priming paradigm with a patient with Wernicke’s aphasia (JM), priming was demonstrated at ISIs of 300, 500, 800 and 1110ms (Prather et al., 1997). Unlike the nonfluent participants and young and elderly controls, JM did not show the typical decline in activation within 300ms of initial priming; instead JM’s priming was sustained over a longer time period. In contrast to the participants with Broca’s aphasia, this broader spectrum of activation, or delay in deactivation, is hypothesised to reflect difficulties of imprecise activation in the lexical semantic network and impaired inhibition associated with more posterior brain regions damaged in Wernicke’s aphasia. It is argued that if weakly semantically related competitors are activated and not subsequently inhibited, this pattern in activation could account for the comprehension deficits seen in Wernicke’s aphasia (Yee, 2005). The explanations provided for the delayed lexical activation in Broca’s aphasia however relate to temporal disruptions which in turn impact on real-time sentence processing and initiation associated with more anterior brain regions. Caution in generalisation of results should be taken however, due to the use of single case methodologies within these studies.

The patterns of semantic priming effect in people with Broca's aphasia has been reviewed and summarised by Del Toro (2000) as follows: (i) more consistent priming has been found in auditory priming compared to orthographic priming, particularly with paired as opposed to triplet presentation of stimuli; (ii) more consistent priming has been found using visual list presentation of stimuli as opposed to paired lexical decision presentation; (iii) significant priming effects are reported when ISIs/SOAs used are 500ms or under (with the exception of Milberg et al., 1987); (iv) in paired lexical decision tasks priming has not been found with SOAs of 1500ms or more; (v) in written paired lexical decision tasks the shortest ISIs to result in significant priming are 300ms (Milberg et al., 1995) and 150ms in an auditory paired test.

Attempts have been made to distinguish between effects of automatic and controlled semantic activation in PWA by varying the experimental SOA, however heterogeneous results are reported. Holderbaum, Mansur and de Salles (2016) present results of a paired written lexical decision priming task, using SOAs of 300- and 500ms to represent automatic and controlled processing. Participants were classified with a range of aphasia syndromes and performance was analysed individually. Only 3/10 PWA demonstrated a priming effect, with three patterns emerging: seven PWA who showed no semantic priming effect; two participants with a priming effect at the longer SOA (one Broca's aphasia and one transcortical motor aphasia); and one participant who demonstrated priming at both SOAs (transcortical motor aphasia). By examining the individual performance of PWA in comparison to explicit semantic tasks, double dissociations were reported. Two individuals presenting with a semantic priming effect showed impaired performance on explicit tasks such as semantic association (Pyramids and Palm Trees Test: Howard & Patterson, 1992) reading comprehension and a read aloud task, whereas the inverse pattern was present for six PWA without a semantic priming effect but with intact performance on the explicit semantic tasks. The authors are clear to note that a lack of semantic priming effect in the study could be due to the small sample size of participants with aphasia (*n*= 11) and the small number of items within the priming task itself.

It is clear from the literature that inconsistencies exist in semantic priming methodologies with PWA, such as variations in ISI, modality and paired versus continuous list presentation of stimuli, leading to difficulties in comparing the disparate findings. To summarise, four main viewpoints on semantic priming in Broca's and Wernicke's aphasia (Yee, 2005) are presented and related to specific methodological choices (Carter et al., 2011).

i) Automatic lexical semantic processing is intact in people with Broca's and Wernicke's aphasia. For Broca's aphasia priming effects have been observed in auditory and written lexical decision priming tasks using short ISIs of 150-300ms (Ostrin & Tyler, 1993; Tyler et al., 1995b; Hagoort, 1997). The failure to show semantic priming effects at long ISIs of 500ms (Milberg & Blumstein, 1981; Milberg et al., 1987) is linked to the strategic processing implicated in tasks with longer ISIs, therefore the lack of a semantic priming effect is proposed to be a result of difficulty using controlled strategies such as post-lexical semantic matching. It is proposed that both groups of PWA experience impaired integration of lexical-semantic information rather than a deficit in the prior automatic activation (Hagoort, 1993; Bushell, 1996).

ii) People with Broca's aphasia present with delayed/slowed automatic lexical activation and people with Wernicke's aphasia present with delayed deactivation of lexical semantic knowledge (Prather et al., 1997; Yee, 2005). It is argued that in Broca's aphasia automatic lexical semantic activation is intact but does not function as efficiently as control groups tested when long ISIs were used (Prather et al., 1992; Prather et al., 1997).

iii) People with Broca's aphasia have reduced levels of lexical semantic activation compared to controls with no language impairment (Milberg & Blumstein, 1981). In Wernicke's aphasia however, typical or increased levels of lexical semantic activation may be observed (Blumstein et al., 1982; Milberg et al., 1987; Baum, 1997), often not in keeping with presentation of semantic knowledge on explicit assessment. There is currently a lack of consensus as to whether the pattern seen in people with Wernicke's aphasia is in fact similar to controls, or one of increased activation (Yee, 2005).

iv) Atypical semantic priming occurs in participants with Broca's aphasia when both short and long ISIs are used (Milberg et al., 1995; Del Toro, 2000), suggesting impaired automatic lexical semantic processing. It is argued that this is masked in studies which posit intact semantic priming in Broca's aphasia, due to an over-reliance on strategic processing as a compensatory strategy. Meanwhile people with Wernicke's aphasia present with intact priming but lack the ability to apply conscious strategy in tasks (Milberg et al., 1995).

Due to the current levels of variation in results and their interpretation, Carter et al., (2011) aimed to better understand the effects of different semantic priming methodology using a control population, to allow findings to be more systematically applied in future aphasia semantic priming research. Twelve young adults completed a semantic priming task with the variables of short ISI (0ms) and long ISI (400ms) crossed with uni-modal (visual to visual) and cross modal (auditory to visual) conditions. Accuracy data showed no main effect of ISI, but higher levels of accuracy in the cross-modal priming condition. Conversely, response latency data showed no effect of modality, but a main effect of ISI, with faster response latencies and greater priming effects in the 0ms condition. As it is argued that expectancy-based strategies can be used with ISIs as small as 250ms (Del Toro, 2000) the authors hypothesise that in the 400ms ISI condition automatic processes may have ended. With regard to the lack of an effect of modality on response latency, if lexical semantic processing required conversion of prime stimuli to target modality, longer response latencies may have been observed in the cross-modal condition. However, the similar response latencies and priming effect between inter- and intra- modality provide evidence of amodal semantic representations, with spoken or written stimuli both accessing a shared semantic system.

Other research findings posit differences between visual to visual and visual to auditory repetition priming in a nonword detection task, and it was suggested that auditory words may require access to phonological codes only, whereas orthographic stimuli access orthographic and phonological codes resulting in a conversion cost before semantic representations are activated (Rugg, Doyle, & Melan, 1993). To address this issue an auditory to auditory priming condition would need to be carried out for comparison.

2.5.3.2 Further variation in semantic priming methods in people with aphasia

In addition to the typical semantic priming methodologies used to investigate semantic priming in PWA, further areas have been investigated including priming with pictures, verbs and the use of visual masking, and traditional experiments supplemented with the use of alternative online methods including neuroimaging and event-related potential techniques.

One cross-modal priming study used picture primes and written target words to assess implicit semantic processing in an individual with non-fluent aphasia and alexia. Semantic priming was demonstrated with an experimental ISI of 500ms despite impaired performance on explicit tests of read aloud and semantic matching tasks (Mimura, Goodglass, & Milburg, 1996).

In addition to nouns, semantic priming has also been explored in individuals with Broca's aphasia using verbs (Faroqi-Shah, Wood, & Gassert, 2010; Myers & Blumstein, 2005). Faroqi-Shah et al., (2010) investigated implicit verb processing to ascertain if body part information is automatically accessed in a semantic priming task. An orthographic paired lexical decision priming task with 200ms SOA was implemented, in which the verb prime implicated either a congruent or incongruent body part, for example preceding the target *licking* with the prime *kissing* versus *clapping*. Six participants with Broca's aphasia demonstrated an interference effect similar to control participants from a previous study (Faroqi-Shah, Gassert, & Wood, 2009) whereby response latency was slowed when prime-target pairs relating to congruent body parts were presented when compared to the neutral baseline and incongruent conditions. The interference effect was not significant when repeated with a longer SOA of 700ms, and disappeared when the experiment was repeated using picture stimuli. Despite the mean response latencies being slower for the PWA group, they presented with an interference effect of similar magnitude to that of the control group, suggesting that automatic activation of semantic verb information is unlikely to be impaired in people with Broca's aphasia. The authors hypothesise that the interference effect suggests that, in line with embodied cognition accounts of language comprehension (Barsalou, 2008), the processing of verbs encompasses mental simulation of the action, and therefore verbs requiring simulation of the same body part (e.g. *kissing-licking*: mouth) cause interference.

A large literature exists with neurologically intact participants regarding the use of forwards and backwards visual masks to reduce or eliminate conscious processing of primes (see Forster, Mohan, & Hector, 2003). Preliminary explorations of masked repetition priming in PWA have been undertaken with the aim to more definitively ascribe priming effects to automatic processing and therefore better interpret the language impairment (Silkes & Rogers, 2010). In one study, Silkes and Rogers (2012) provide evidence that priming occurs for people with either fluent or nonfluent aphasia in a forwards and backwards masked repetition priming task, but to different temporal parameters to control participants. People with aphasia demonstrated priming at a 250ms ISI only, in comparison to the control group who demonstrated priming from 50- to 1000ms. These differences are argued to represent a slowing of activation in comparison to typical processing, and also impaired maintenance of activation representation due to impaired automatic spreading of activation for language processing. A role for implicit repetition priming has since been highlighted in naming therapy for anomia (Silkes, Dierkes, & Kendall, 2013; Silkes, 2015). Masked semantic priming in PWA is yet to be investigated.

Online neuroimaging techniques have used semantic priming as a tool to investigate the neural correlates of semantic processing, using for example positron emission tomography (PET; Mummery et al., 2000), functional magnetic resonance imaging (fMRI; Copland et al., 2003; O'Hare, Dien, Waterson, & Savage, 2008; Rissman, Eliassen, & Blumstein, 2003; Rossell, Price, & Nobre, 2003; Sachs et al., 2008), magnetoencephalography (MEG; Zipse, Kearns, Nicholas & Marantz, 2011) and event related potential measurements (ERP; Matsumoto, Iidaka, Haneda, Okada, & Sadato, 2005). Event related potentials demonstrate neurobiological electrical activity via placement of electrodes on the scalp; the N400 is a negative reduction in the ERP that peaks approximately 400ms after the presentation of a stimulus. The N400 component of ERP output is evoked by semantic variables or anomaly, for example unimpaired control participants demonstrate a larger decrease in the N400 waveform in response to targets preceded by unrelated words in comparison to related words in semantic priming tasks (Rossell, Bullmore, Williams, & David, 2001; for reviews see Kutas & Federmeier, 2000; Lau, Phillips, & Poeppel, 2008).

Semantic priming effects have been investigated in PWA using event-related potential methods (Hagoort, Brown, & Swaab, 1996). Event-related potentials of participants with Broca's (*n*= 13) or Wernicke's (*n*= 7) aphasia were measured whilst listening to auditory word pairs. This allowed a time-sensitive measurement of post-synaptic activity of groups of neurons to be monitored. Within the study the legitimacy of syndrome classification was raised, therefore participants were also classified into low and high comprehender groups. The high comprehenders performed similarly to control participants, whereas the low comprehenders showed a reduced N400 effect, indicative of impairment in the ability to match words based on semantic similarity or association. Semantically related and associated word pairs were separately investigated, but no effects of relationship found. No qualitative difference in the pattern of performance was noted between people with Broca's and Wernickes' aphasia.

2.6 Chapter summary

Collectively, the evidence reviewed here suggests a potential role of semantic priming in elucidating lexical semantic processes in PWA, particularly when compared to performance on explicit semantic assessment tasks. Overall, some evidence indicates that semantic priming occurs for PWA, but with different temporal parameters to unimpaired speakers' lexical semantic processing, and may vary by aphasia subtype. However it is noted that the classification of PWA into fluent and non-fluent has its limitations, and may be a relatively arbitrary distinction to apply in this context. The studies discussed remain relatively narrow in focus, lacking overall homogeneity in methods and have small sample sizes, making between study comparisons challenging. There remain several aspects of semantic priming in aphasia about which relatively little is known, including the role of semantically similar versus associative relationships in priming, differences in priming within or between spoken and written modalities, and methodological decisions to reduce the influence of strategic processing on testing, including variations in ISI, use of pairwise versus continuous list presentation, and forwards or backwards masking.

The current study aims to address some of these questions surrounding implicit assessment of semantics in PWA in a case series comparison of PWA and a group of aged-matched control participants. Implicit assessment of lexical semantics via use of a semantic priming task is investigated in relation to performance on psycholinguistically-matched explicit tests of lexical semantics, and considered in the context of participants' language and cognitive profiles.

2.7 Project aims and research questions

Three experimental semantic tasks were developed to assess lexical semantic processing in control participants and PWA. The three semantic experimental tasks central to the project were:

1. Written word presentation Semantic Priming (SP)
2. Written Word-Picture Verification (WPV)
3. Written Word-Picture Matching (WPM)

The overarching aim of the project was to investigate of the validity of these semantic processing tests. The following research questions were considered:

1. Is there coherence in performance across implicit and explicit semantic tasks in neurotypical control participants and PWA? Are explicit semantic tasks over-diagnosing semantic impairment in PWA? Can retained semantic processing be revealed via an implicit semantic task in PWA who present as impaired in explicit tasks?

2. Is semantic processing influenced by the nature of stimuli semantic relationship, i.e. whether prime or distractor items are semantically similar to or associated with the target?

3. Is semantic task performance predicted by scores on language and other cognitive tests? If so, is there evidence that executive control of semantics is a factor?

2.8 Project objectives

The objectives of the research project were:

1. To compare control participant and PWA performance across three psycholinguistically-matched, lexical semantic experimental tasks: an implicit Semantic Priming task, and Word to Picture Verification and Word to Picture Matching tasks that require explicit semantic judgement.

2. To evaluate the performance of PWA on the experimental semantic tasks in relation to their performance on standardised tests of lexical semantics.

3. To evaluate relationships between the performance of PWA on the experimental semantic tasks and standardised tests of cognition that assess attention, short-term memory and executive function.

The three experimental semantic tasks were used to explore the following specific research questions:

1. **Semantic Priming**
    a. Do control participants demonstrate a semantic priming effect?
    b. For control participants demonstrating a priming effect, is this due to priming from semantically similar primes, associated primes, or both?
    c. Do the PWA group demonstrate a semantic priming effect?
    d. For PWA demonstrating a priming effect, is this due to priming from semantically similar primes, associated primes, or both?
    e. Do the control group and PWA group show similar priming effects?
    f. How does individual PWA performance on the SP task in compare to the control group?

2. **Word to Picture Verification**
    a. Are there differences in performance on the WPV task for the control and PWA groups?
    b. How does individual PWA performance on the WPV task compare to the control group?

3. **Word to Picture Matching**
    a. Are there differences in performance on the WPM task for the control and PWA groups?
    b. Do the control group and PWA group show similar patterns in the type of errors made in the WPM task?
    c. How does individual PWA performance on the WPM task compare to the control group?

4. **Experimental semantic tasks**
    a. Are there within- and between-group differences in performance across the three experimental semantic tasks?
    b. Are there relationships between experimental semantic task performance for the control and PWA groups?
    c. Do subgroups of patterns in performance emerge for the PWA across the experimental semantic tasks?

5. **Semantic and cognitive tasks**
    a. Is there a relationship between performance on semantic and cognitive tests, and performance on the experimental semantic tasks for the PWA group?

The three experimental semantic tasks will be discussed in Chapter 3, including criteria for the three corresponding word sets and their psycholinguistic matching to allow for comparison between tasks.

Chapter 3 Experimental semantic tasks: development of word lists and methodological considerations

3.1 Semantic tasks and their cognitive requirements

Three experimental semantic tasks were developed to assess lexical semantic processing in control participants and PWA. The control participants provided normative data representing typical processing across the experimental semantic tasks, and allowing comparison to the PWA.

The processing demands of the three tasks vary. Semantic priming (SP) assesses semantic knowledge implicitly and arguably with less additional cognitive skill in comparison to word-picture verification (WPV) and word-picture matching (WPM) tasks. Written WPV assesses semantic processing using pairs of items, and written WPM is a typically used measure of single word comprehension in PWA, with multiple picture stimuli; both tasks require an explicit decision regarding word meaning, and task performance requires a range of additional cognitive skills. The processing requirements of the three semantic tasks are explored in more detail below.

3.1.1 Semantic priming

Many variations in semantic priming methodology exist, which potentially affect task demands. These include: the task itself, for example, lexical decision or word naming; task modality - written, spoken or picture; presentation of items - continuous list versus paired presentation; and factors affecting the possibility of conscious or strategic processing, such as inter-stimulus intervals (ISI), and stimulus-onset asynchronies (McNamara, 2005). In the experimental SP task used within the current project, a written lexical decision task with continuous list presentation was employed. Task demands will be discussed in light of these methodological choices.

As discussed in Chapter 2, in SP tasks semantic knowledge is assessed implicitly without participants making explicit decisions about word meaning. In the current SP task, explicit lexical decisions are required about written words, i.e. whether each item is a real word or nonword, however this conscious decision does not require, although it may invoke, lexical semantic processing. This is in contrast to the WPM and WPV tasks, in which conscious decisions are made regarding word meaning. Performance on the SP task requires letter and word recognition, and access to the input orthographic lexicon to make accurate lexical decision judgements (Whitworth et al., 2014), plus a decision indicated by a yes/no motor response via button press. Unlike WPM and WPV tasks, in SP participants see only one written stimulus per trial with no requirements to process and inhibit responses to distractor items. Sustained attention is required, however attention is not required to shift between different stimuli within one array, only between subsequent words appearing within the list. Thus, arguably less additional cognitive processing is required in SP compared to WPM and WPV. In the current SP task there is no time between response and the subsequent trial, and participants are instructed to respond as quickly as possible, therefore the rapid and time-limited nature of the task may add an additional processing component of speed to the task.

3.1.2 Word to picture verification

Following Wingfield's (1968) original work, variants of WPV tasks have been used. The task has been adapted according to specific experimental aims, including investigation of the time frame of picture recognition (Özdemir, Roelofs, & Levelt, 2007; Levelt et al., 1991), the effects of frequency on picture recognition (Jescheniak & Levelt, 1994), and a control measure of picture recognition times for naming (Stadthagen-Gonzalez, Damian, Pérez, Bowers, & Marín, 2009). However, WPV, involving matching a word to a picture, is infrequently used as a semantic processing task in studies with PWA. In WPV tasks one word and one picture are displayed. Typically a written word is presented, (e.g. Jescheniak & Levelt, 1994) however in some studies an auditory word is used (e.g. Levelt et al., 1991). Following a brief pause, such as 200ms, either a matching or unrelated picture is then displayed. Participants decide if the word and picture match. In some experimental designs the picture is presented before the word (Dräger, Breitenstein, Helmke, Kamping, & Knecht, 2004; Theios & Amrhein, 1989).

To use WPV to assess semantic processing, the relationship between the word and the image in the incongruent condition can be manipulated according to the semantic relationship between the two. There are a handful of studies utilising WPV with PWA, for example Rapp and Caramazza (2002) make reference to an auditory word/picture verification task with patient KSR. Howard and Gatehouse (2006) highlight semantic impairment in two PWA (JGr & KS) through use of a WPV task using correct picture names and semantically and phonologically related foils. Breese and Hillis (2004) argue that WPV is a more sensitive task than word to picture matching for identifying auditory comprehension deficits. In their study including people with left hemisphere stroke, 46/59 participants (78%) performed more poorly on a WPV task than a WPM task, with participant acceptance of incongruent word-picture pairings *and* congruent word-picture pairings deemed to represent impoverished semantic representations. The authors further recommend the use of WPV over WPM tasks as they require more typical responses: for example functional communication is more likely to be based around comprehension and responses to yes or no questions rather than multiple choice questions and answers. Currently there is no published aphasia test battery which encompasses a WPV task for PWA.

Successful performance on the WPV task requires access to lexical and visual semantics, comparison of the two stimuli cross-modality, judgement of semantic similarity, and an explicit decision based on their similarity. Like WPM, the task requires a range of cognitive processes including sustained attention, perceptual processing, inhibition, selection and a motor response to signal choice. Unlike the WPM task, WPV does not involve processing of multiple images and concurrent inhibition of the semantic and phonological representations of these. The decision requires a yes/no button press or pointing motor response; WPM tasks involve selection of the target from a choice where the correct match is present at all times, whereas the word-picture verification is either correct or incorrect. The binary nature of the WPV task may deter its use, due to the 50% chance of correctly identifying the target or rejecting the semantic distractor in each trial, and the possibility of participant response bias (Breese & Hillis, 2004). Arguably the WPV task may be more difficult for people with semantic impairment or who have difficulties with semantic inhibition, as having just one semantic distractor forces the individual to consider the word-picture semantic relationship and the potential names for the picture (Whitworth et al., 2014).

Currently, there is a lack of evidence of how participants perform the WPV task. Three descriptions of serial stage processing required to perform a WPV task have been proposed, *visual matching*, *conceptual matching*, and *lexical matching* (Santiago et al., 2000, Stadthagen-Gonzalez et al., 2009). In the *visual matching* explanation, participants visualise an image when presented with the written target word, subsequently comparing this to the visual features of the picture with which they are presented. In this scenario, where the word has already been processed, response latency would be interpreted to indicate the visual-perceptual processing requirements of the picture. According to a conceptual matching account, participants access the semantics of both the word and the picture stimuli separately for subsequent comparison (Theios & Amrhein, 1989). Response latencies, according to this account, would include processing time of the semantic information about the picture, not solely visual-perceptual information. If lexical matching occurs within the task, then response latencies would be dependent on the time taken to perceive the picture, access the semantics, covertly name it, and then compare the picture name to the written stimulus. There is evidence in support of the lexical matching account from naming tasks, which demonstrates that in naming target pictures, distractor items are unconsciously phonologically encoded in addition (Morsella & Miozzo, 2002; Meyer & Damian, 2007), however it remains unclear as to whether this remains the case in tasks such as WPV in which no spoken output is required (Stadthagen-Gonzalez et al., 2009). The written word can be presented for a long exposure time before the picture (1000ms), to ensure that the semantic representation of the written target word is encoded before the picture appears and visual processing of the picture begins. Response latency is thus taken as an indication of speed of picture recognition (Stadthagen-Gonzalez et al., 2009).

3.1.3 Written word to picture matching

In a written WPM task, respondents are required to silently read a single written word and choose the picture that corresponds to the word from a set of line drawings. The WPM assessment method has developed over time since the 1970s when Pizzamiglio and Appicciafuoco (1971) generated three Italian tests of word comprehension. As part of wider research to differentiate between aphasic impairments of semantics, syntax and phonology, each test focused on one component of processing. In the semantic test the array of picture choices included the target and a range of semantic distractors. The tests were subsequently adapted for English use by Lesser (1974). In the 1980's Bishop and Byng (1984) developed the WPM task further in The Test for Lexical Understanding with Visual and Semantic Distractors (LUVS). Both semantic and visual distractors were included so that inaccurate responses were not restricted to solely semantic comprehension errors. The inclusion of different distractor types in WPM tests allowed patterns of incorrect distractor choice to be identified, thus supporting differential diagnosis of aphasia impairment. For example, it could be considered that due to perceptual deficits, errors may transpire for visually similar items (Kay et al., 1992). This principle was subsequently applied to word comprehension assessments that are currently used; typically, there is an array of four (see the Comprehensive Aphasia Test (CAT); Swinburn et al., 2004) or five pictures (see Psycholinguistic Assessments of Language Processing in Aphasia (PALPA); Kay et al., 1992) including one unrelated distractor and at least one distractor that is semantically related to the target. The PALPA was developed from the LUVS and features two semantically related distractors (one distant and one close relationship), one visually similar distractor and one unrelated distractor. In the CAT, alongside the semantic and unrelated distractors, a distractor picture that is phonologically related to the target word is included. The range of potential distractor types may therefore result in specific errors patterns, highlighting specific processing impairment in PWA. Variations exist in other aphasia language batteries used more widely outside of the UK, such as the Boston Diagnostic Aphasia Examination (BDAE, Goodglass & Kaplan, 1972) and the Western Aphasia Battery (WAB, Kertesz, 1982).

A number of theorists (e.g. Butterworth, Howard & McLoughlin, 1984; Cutler, 1981; Kay, Lesser & Coltheart, 1992, 1996; Shallice, 1987) have proposed that error patterns in language tasks reflect the level of functional impairment in the language processing system. Notably, a preponderance of semantic errors is thought to reflect a central semantic deficit (e.g. KE: Hillis, Rapp, Romani, & Caramazza, 1990; JCU: Howard and Orchard-Lisle, 1984; Howard & Gatehouse, 2006) or an impairment with access to or from semantic representations (e.g. AR: Warrington & Shallice, 1979). A preponderance of phonological errors is symptomatic of input phonological processing impairment (e.g. JS: Caramazza, Berndt, & Basili, 1983). Finally a preponderance of visual errors may indicate visual processing difficulties (e.g. Silveri & Leggio, 1996). Response patterns are unconstrained within output tasks such as naming, unlike WPM comprehension tasks where responses are limited by the choice of distractors such as unrelated, phonologically related, or semantically related (Whitworth et al., 2014). In particular, in output tasks the types of semantic error made, such as coordinate, subordinate or associative, may provide information regarding an individual's impairment (Coltheart, 1980; Nickels, 1997), whereas semantic error types in WPM are constrained by the type of semantic distractor relationships that are included in each assessment.

A variety of skill and processing ability is required for successful engagement with a WPM task, including the ability to make an explicit decision to match the target word to the appropriate picture. Requirements will vary slightly depending on the auditory or written nature of the task. As the modality in the current study is written comprehension, written WPM will be considered from here on. In addition to cross-modality lexical and visual semantic processing, successful performance involves a range of additional cognitive skills, including visual and auditory attention, visuo-spatial processing, visual short-term memory, inhibition of distractors, selection of a stimulus, and a motor response to signal choice. Selective or focused attention is required to maintain attention (Zomeren & Brouwer, 1994) throughout the duration of the assessment, and furthermore to alternate between stimuli in an array, ultimately ignoring distractors and focusing on the target picture. Attention must then be refocused to new target items within each subsequent trial. These different facets of attentional abilities can be impaired post-stroke, including for PWA, thus affecting language comprehension abilities (Tabor Connor & Fucetola, 2011; Murray, 2002). In addition to attention, visual-perceptual skills may be impaired post-stroke and could affect the ability to process written stimuli and visually scan and process images within a WPM array (Heuer & Hallowell, 2007). While scanning the array, the target word is likely to be held in short-term memory, and incorrect responses to distractor items need to be inhibited. Once the correct picture has been identified, participants are required to indicate choice by pointing to the picture, requiring coordination and execution of motor skill which may also be impaired post-stroke.

3.2 Design

A repeated measures study design was chosen, with participants completing all three experimental semantic tasks. To allow for direct comparison of participant performance, three experimental word lists were derived and each one assigned to a semantic experimental task. Triplets of target words were matched on the psycholinguistic variables of lexical frequency, imageability and length, to form three sets of 50 targets appearing in each task. Different stimuli were included in each task in order to avoid inadvertent repetition priming of representations through prior exposure, which is well documented (see Schacter, 1987, for a review; see also Forbach, Stanners, & Hochhaus, 1974 and Scarborough, Gerard & Cortese, 1979 for repetition priming in lexical decision tasks).

3.3 Word list construction and stimuli selection criteria

3.3.1 Design of lists

In the first stage of designing matched word lists across the three experimental semantic tasks, the researcher identified 150 potential target words and 150 potential partner words to act as primes in the semantic priming task, or semantic distractor pairs in the word to picture verification or word to picture matching task. The primes/distractor words were either semantically similar to or semantically associated to the targets.

The pairings were made with key considerations:

1. Criteria for the types of nouns selected as lexical stimuli (see section 3.3.2).
2. Matching on the psycholinguistic variables of frequency, imageability and length:
    a. of targets between the three experimental semantic tasks
    b. of semantic or associative partners to their targets between the three experimental semantic tasks
    c. of targets, phonologically related, and unrelated distractors in the word to picture matching task.
3. Semantic relatedness and association between the targets and their partners. Target stimuli words were chosen that could feasibly be paired with a semantically similar or associated partner, which could act as the prime in the SP task and semantic distractor

in WPV and WPM. For example, *carrot* - *leek* are semantically similar, *porridge* - *spoon* are associated; a full account of the selection process is provided in section 3.3.3.4.

4. Targets and semantic, associated, and unrelated partners were checked against criteria to ensure minimum phonological or orthographic overlap (whereas phonological distractors in the WPM task were chosen on the basis of phonological overlap).
5. Selection of word pairs was made with consideration of the individual semantic task requirements, for example the need for all targets in the WPV tasks and all stimuli in the WPM task to be unambiguously recognisable from a picture.

The stimuli criteria for inclusion and exclusion will be discussed in turn below, and the rationale for each provided, including those of lexical status, frequency, imageability, length, phonological and orthographic overlap, and matching of stimuli to task requirements. A preliminary set of matched target and partner words was then rated for semantic and visual similarity (see Chapter 4) before the word lists were finalised (see final word lists in Appendix A).

3.3.2 Noun criteria for the experimental word lists

All target words and partners were common nouns (e.g. *jumper, sausage*). In composing the word lists, the frequency ratings for noun and verb forms of lexical items were collected from the British National Corpus Web (BNC: British National Corpus Consortium; 2007), to control for the confound that many nouns can also exist as verbs (e.g. *foot* as in ‘foot the bill’, *coin* as in ‘to coin a phrase’, *worm* as in ‘to worm your way out of something’). In the final word lists of 300 prime/distractor and target words, 111 items also had status as verbs, however, it was confirmed that the noun forms had higher frequency ratings than the verb forms, except for three items.[1]

All items were singular nouns, with the exception of five stimuli which were included in their plural form for the relation to the target word to be legitimate. There were three instances where associated pairs for target words had to be plural rather than singular forms for the association to be legitimate: *bubbles* paired with the target *bath*; *ducks* paired to the target *lake*; and *wellies* paired to the target *puddle.* In these cases there was a higher associative relationship for the plural as opposed to the singular form of the words, as measured by the Edinburgh Associative Thesaurus (Kiss, Armstrong, Milroy, & Piper, 1973). *Pebbles* was a semantically similar pairing for the target *sand,* whereas the singular form *pebble* was not

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[1] The prime *handle* in the SP task, target *rose* in the WPV task, and target *bear* in the WPM task had higher ratings in their verb status compared to their noun status.

deemed to be. Finally, in the WPM task the plural item *stars* was a phonologically matched distractor for the target *vase*, as the singular form *star* does not rhyme with the target.

Lexical items with a single meaning were sought, to avoid the possibility that word recognition would be delayed by lexical items with multiple, competing meanings, for example in cases of homographs, such as ‘bank’(Rodd, Gaskell, & Marslen-Wilson, 2002). Lexical items which could have two or more possible meanings (homographs; e.g. *ruler* – a form of measure vs. a head of state) were avoided for the target words. However there were exceptions such as *nail* and *boot*, where stimuli were included to meet the primary consideration of psycholinguistic matching. In some cases where there were no appropriate alternatives to meet the psycholinguistic matching criteria, homonyms (such as *skate*: the sports shoe vs. the fish; *wood*: the material vs. area with trees) were selected as distractor items in the WPM task rather than appearing as targets or related pairs, as any responses to these items would be error responses and therefore excluded from analyses.

Compound nouns (such as *chestnut*, *corkscrew*, *seaweed)*, or words which contain another lexical item (for example, *cauliflower*, *dandelion)* were excluded to avoid lexical overlap or relatedness to other stimuli, which would result in repeated exposure of lexical units (e.g. *lion* and *dandelion*) or undesirable priming effects if parts of the compound words were inadvertently related to other items in the list (e.g. cauli*flower* and *rose*). Words which might evoke unpleasant negative reactions were also avoided such as *coffin* and *grave,* as it has been shown that individuals respond differently to emotionally significant as opposed to neutral words, for example in terms of recognition memory (Kensinger & Corkin, 2003) and attentional processes (Williams, Mathews & MacLeod, 1996). Kissler, Herbert, Peyk, and Junghofer (2007) reported ERP effects in unimpaired control participants that emotionally arousing written words enhanced mainly a left occipito-temporal negativity, the spatial distribution and time course of which suggested that words with emotional salience amplify early stages of semantic processing. All three lists were designed to contain both animate and inanimate entities within which there were semantic subcategories such as birds, animals, food, and body parts.

All of the above factors were considered when identifying lexical stimuli to be psycholinguistically matched across the semantic experimental tasks. In addition, when allocating target pairs to each list, the nature of the experimental tasks was considered. For example, in the SP task stimuli were presented as written words, therefore were not required to be picturable but were required to be orthographically and semantically unambiguous. Only targets with a suitable phonological distractor could be included in the WPM task.

3.3.3 Psycholinguistic variables

Psycholinguistic variables are known to affect the speed of lexical processing including word imageability (Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004), concreteness (Eviatar, Menn, & Zaidel, 1990), frequency, (Gernsbacher, 1984; Lambon Ralph, Graham, Ellis, & Hodges, 1998; Rubinstein, Garfield & Millikan, 1970; Scarborough, Cortese, & Scarborough, 1977), age of acquisition (Brysbaert, Van Wijnendaele, & De Deyne, 2000; Juhasz, 2005), and length (Andrews, 1997). As is standard in psycholinguistic research, the three word lists were matched on the key psycholinguistic variables of imageability, frequency, and length, including number of syllables, letters and phonemes. Triplets of appropriate target words with similar psycholinguistic variable ratings were identified; one target of each triplet was assigned to one of the three semantic experimental tasks.

3.3.3.1 Imageability

Imageability ratings were obtained from the online MRC psycholinguistic database (Coltheart, 1981), a resource detailing psycholinguistic properties from a range of other smaller databases. Imageability ratings within this source are derived from the combination of three sets of norms: Paivio (unpublished expansion of norms of Paivio, Yuille, & Madigan, 1968); Colorado (Toglia & Battig, 1978); and Gilhooly & Logie (1980). Imageability values range from 100 to 700 (min = 129; max = 669; *M* = 450; *SD* = 108). Imageability ratings are not provided for all word entries in the database. Entries were not obtainable for some experimental stimuli (see section 4.7.1.1 and Appendix A for details). Imageability ratings did not exist for the four plural nouns within the word lists (*bubbles, pebbles, ducks, wellies*) therefore the singular imageability rating was used, except for *wellies* which was not listed in its singular form *welly*.

3.3.3.2 Frequency

Written word frequency ratings were taken from the BNC (2007) rather than Kucera-Francis ratings (1967) or measures that contained American English samples. The Kucera-Francis ratings of word frequency became the gold-standard of frequency measures as demonstrated by the number of research publications that continue to cite them post-publication. This may be due to perceptions of the corpora as being a more contemporary and adult-based representation (Brysbaert & New, 2009) compared to earlier measures such as the 1942 Thorndike and Lorge frequency counts which included children’s material in their analysis. However, the Kucera-Francis corpus has received criticism for the small corpus size (Burgess &Livesay, 1998), poor validation when compared to alternative frequency measures and poor correlation with lexical decision and naming latencies (Balota et al., 2004).

As a British-based, modern corpus, BNC written frequency values were derived for the experimental task stimuli within the current study. The BNC*web* (2007) is an online resource which serves as representation of late 20th century spoken and written British English. It contains 88 million written word samples gathered from a range of sources including newspapers, fictional and academic books, and journals up to 1994.

3.3.3.3 Length

Word length measurements were also collected from the MRC psycholinguistic database including number of syllables, phonemes and letters in each word. For some items estimates of number of syllables were missing or errors were present in the values provided. The researcher therefore rated such items and an independent phonetician and two speech and language therapists subsequently provided inter-rater reliability checks and validation of these. For example *chocolate* is classified by the MRC as having three syllables, whereas it was independently agreed that it should be classified as a two syllable word.

3.3.3.4 Lexical semantic similarity and association

As discussed previously in section 2.4.2.4, it is disputed within the literature whether the semantic priming effect occurs due to lexical semantic similarity or association. Within some semantic priming experiments the types of relationship between words are classified as coordinate, subordinate, instrument (e.g. *broom - floor*) or script (e.g. *restaurant - wine*) (Moss et al., 1995; Tyler et al., 1995). Within the current study, items with instrument and script relations were classified under the umbrella term associated, as they co-occur thematically, but they do not share semantic features. Within the semantic experimental tasks, each target word was paired with either a semantically similar word with low association, or an associated word with low semantic similarity, allowing for the effects of both type of relationship to be investigated independently.

In each list of 50 targets, the researcher first identified 32 targets that were paired with a semantically similar word with low association. The partner words were semantic category coordinates of the targets, for example the target *badger* and the semantically similar partner *squirrel*, and where possible had low association (10 or below[2]) as rated by the Edinburgh Associative Thesaurus (Kiss et al., 1973). The most obvious coordinate choices often did not meet the criterion of low association, as many coordinates are both semantically similar and

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[2] There was one instance of a prime to target association higher than 10 for the pair *television - radio* in the WPV task.

associated e.g. *thumb – finger*, therefore these cases were excluded. Where more than one partner choice with no association was available, semantically similar pairs were chosen that matched most closely in frequency to the target partner. The remaining 18 targets were paired with words deemed to be associated that were not semantic coordinates e.g. *honey-bear,* as judged by the researcher. The majority of these could be classified as possessing script relations, in which items are part of the same script or schema (see Rumelhart et al., 1986). Ratings of semantic similarity between word pairs were not available. Pairings were classified by the researcher as being semantic coordinates and then verified by collecting ratings of the semantic similarity from neurologically intact participants using a semantic similarity rating task (see section 4.3.1).

Word association norms were taken from the Edinburgh Associative Thesaurus (EAT, Kiss et al., 1973). The EAT is an online resource compiled of free association norms generated by 100 students. In the Kiss et al. (1973) study, participants were shown one written word at a time and asked to write down the first word they thought of in response. The task is classified as *free* association as participants were not restricted to responses from particular categories and as *discrete* as responses were limited to one response per target (Kostova & Radoynovska, 2008). There is debate within the literature regarding the most valid method of investigation for word association norms, for example, in continued association participants are encouraged to think of more than one response per target (De Deyne & Storms, 2008; Thompson-Schill, Kurtz, & Gabrieli, 1998). The EAT was deemed to be suitable as it is widely used within the semantic priming literature and collection of independent word association norms was beyond the scope of the current study. Within the EAT, word associations are recorded as proportions of occurrence i.e. the frequency with which a word is provided by participants, divided by the total number of responses. Note that association between two words is different if measured in the opposite direction.

Ratings were not available for all primes or distractor items within the current study (see Appendix A for final word lists and association ratings) and there were no exclusion criteria for association ratings for targets and associated partners. For example some items were not listed, and associations for items in the final word list ranged from 0-45. The direction of association used within the experimental semantic tasks was partner to target, as in SP and WPV the prime (SP) or distractor (WPV) appears before the target. This rule was generalised to the WPM task. The WPM task was monitored for association between items within an array so that there was no shared association between targets and phonological or unrelated distractors. Association ratings were recorded between the four stimuli that would appear together within each trial. Association was identified in the direction of targets to phonological and unrelated stimuli, and also from both phonological and unrelated stimuli to the other three stimuli in their array (target, semantically similar or associated distractor, and unrelated or phonological distractor).

3.3.3.5 Effects of phonological and orthographic relatedness on word processing

Robust effects of phonological and orthographic priming are firmly established with faster response latencies demonstrated to targets that are primed by phonologically similar words (Humphreys, Evett, & Taylor, 1982) and phonologically and orthographically similar nonwords (Grainger & Ferrand, 1996). In the current study phonological and orthographic similarity between target words and their partners was minimised by avoiding pairing items that shared the same initial sound or letter where possible, however there were four instances where this was unavoidable if no other suitable semantic coordinate or associative partner was available[3] (e.g. *tooth* - *tusk*). For example, an obvious semantic coordinate for the target *soldier* would have been *sailor*, but this option was discounted due to being phonologically similar and having an association rating of 8. For this pair *pilot* was chosen instead as it does not share the same phonological onset as *soldier* but is semantically related with 0% association on the EAT, therefore meeting the criteria for both phonological dissimilarity and semantic similarity. In the WPM task the phonological distractors were required to be phonologically similar to the targets with which they were presented, sharing either phonological onset or rhyme. Unrelated distractors were chosen that did not share phonological onset or rhyme with the target, as this would confound their role in the trials.

3.3.3.6 Images

In language assessments, black and white line-drawings are typically used to represent concepts. In the experimental semantic tasks in the current study, colour photographs were used to depict the stimuli more realistically and show more fine grain differences between items (e.g. *toffee – chocolate)*. Accessible information studies with PWA demonstrate varied personal preference as to the type of visual support provided, including Microsoft ClipArt™, symbols, line drawings, and photographs, however Rose, Worrall, Hickson, and Hoffman (2012) report a preference for photographs in PWA.

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[3] Exceptions within the 250 pairs include four pairs with shared onset: *tusk* - *tooth* (SP), *wand* - *wizard* (WPV), *cuff* - *collar, bubbles* - *bath* (WPM); and five pairs which had the same orthographic onset but different phonemes, for example, *toe* - *thumb*, *slipper* - *sock* (SP), *stapler* - *scissors*; *champagne* - *cider* (WPV); and *sponge* - *soap* (WPM). Orthographic similarity may be of less concern in WPV and WPM however, because images, as opposed to written words, are used for distractor items. This is in contrast to the semantic priming experiment in which both the prime and target appeared as written words.

In the tasks where items were required to be picturable (WPV targets and all WPM stimuli) the words to be included in the tasks needed to be easily depicted as such by one image. Some lexical items initially identified as being good matches in terms of psycholinguistic matching were not suitable for the WPM task as they were not likely to be easily identified from a photographic image, for example, *shadow*, *dungeon*, *hurricane*. Further items were not suitable as a range of lexical terms could be applied to the image, for example *lawn* which would likely be identified primarily as *grass,* or *juice* which could be perceived as *drink* or *orange*. Other words such as *lorry* or *truck* were not sufficiently visually distinguishable to ensure that the photograph represented the intended lexical item unequivocally.

Images were sourced that represented typical exemplars of each lexical item. Photographs of the targets and pairs were taken by the researcher, or chosen from a copyright-free photographic resource (Hemera Technologies Inc). The remainder of the photographs were purchased from a royalty-free image bank (Fotolia.com) or sourced from a variety of websites which give permission for copyright free images to be downloaded and used free of charge. Copyright free image websites used included Morguefile, Flicker Creative Commons for images with an attribution license, and Stock.XCHNG.[4]

In the WPM multiple-choice task, image size was consistent in that images were included with a maximum height and width and use of white background where possible to avoid the “pop-out” effect (Wolfe, 2000) of certain items in an array. Pop out effects can result if basic visual characteristics of images are not controlled, in which case individuals’ attention may be drawn to particular test items disproportionately and unintentionally, because of their different characteristics. Examples of physical characteristics of the stimuli include colour, size, complexity; or semantic content such as scene background content or social and cultural influences. By maintaining equal size and reduction in scene background the researcher sought to address some of these confounds. This may be particularly important for PWA who may have concomitant visual acuity or visual attention deficits post-stroke (Heuer & Hallowell, 2007).

One confound in using photographs as opposed to line-drawings is the effect of additional context on picture recognition, for example if the item *microscope* were presented in the context of a lab setting rather than presented on a white background, additional visual-semantic cues may aid recognition, but also may provide distracting information. There is

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[4] Websites used for copyright free images include: Morguefile (http://www.morguefile.com/); Flicker Creative Commons (http://www.flickr.com/creativecommons/ http://www.flickr.com/creativecommons/by-2.0/); and Stock.XCHNG (http://www.sxc.hu/). Photographers were contacted regarding the use of their images and will be attributed as per the guidelines of each website in any publication of materials including the images.

some limited evidence that people with aphasia find high-context photographs facilitative to reading comprehension compared to low-context photographs (Dietz, Hux, McKelvey, Beukelman, & Weissling, 2009). The amount of visual context provided with the image was therefore limited to minimise the potential confound of context on recognition time. Images were obtained with a white background, or were cropped to remove additional background context, for example, removing the lake in the background of *ducks* or the sky from the photograph of *glider*. For a proportion of photographs the background was required to enable the recognition of the image as the intended concept, (e.g. leaving the bowl in the photo of *porridge,* or the sky in the photo of *ocean)*, or because the item already filled the space (e.g. *sand*). 7/50 items in the WPV task and 24/200 in the WPM task did not have a white background[5].

To further control the amount of information present in the images, extraneous or distracting information was edited out. Potentially distracting objects were removed in some instances, for example a padlock at the forefront of the photograph for *canal*, or light fittings in the photograph of *bar,* which dominated the photograph. In some instances text was removed so that participants were not distracted by trying to read text on the photograph. For example the written word ‘circus’ in the photo of *circus* or the brand of electrical equipment in the *telephone, radio* and *television* images.

In three photographs in the WPV task a particular part of the image had to be recognised, therefore a blue arrow was added to the image for orientation purposes. Arrows were not used in the WPM task in which four images appear together, to avoid the potential of their drawing the participant’s attention to single items unintentionally.

Visual similarity between items in an array may also be distracting for participants and affect response time to the target, particularly if post-stroke visual-perceptual processing impairments are present. Target and semantically similar coordinate pairs often share visual features (Cole-Virtue & Nickels, 2004a), potentially confounding decision time in the WPM task. For example *kitten* and *puppy* may look more visually similar than other distractors in the array. The unrelated and phonological distractors identified by the researcher were chosen to be visually dissimilar to their target pairs with which they would appear. Visual similarity ratings were then collected from control participants via a rating task designed to measure the perceived visual similarity between items, and therefore control this factor within the WPM task (described in section 4.3.2).

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[5] Items without a white background: WPV- canal, chin, circus, lung, moon, puddle, tongue; WPM- bar, blossom, bubbles, bush, clothes, copper, fountain, gym, hedge, hill, lake, lightening, lock, ocean, path, pea, pebbles, road, sand, snow, sun, spot, tree, web.

3.3.4 Section summary

In accordance with the considerations made regarding selection of stimuli, preliminary sets of 50 target words and 50 partner words were identified and allocated to a corresponding semantic task, including 50 additional phonological distractors and 50 unrelated distractors for the WPM task. Consideration was given to grammatical class, psycholinguistic matching between lists and between stimuli pairs, the semantic or associative relationship between target and prime or distractor word pairs, phonological overlap, and the pictures used to depict concepts in WPV and WPM. This demonstrates the complexity of considerations required in designing language comprehension assessments.

Before the lists could be finalised, normative data collection for semantic similarity between the proposed semantically related word pairs, visual similarity of images used in WPV and WPM, and name agreement for all images had to be completed, and are described in Chapter 4. At the end of Chapter 4 the three finalised and psycholinguistically matched experimental word lists are presented.

Chapter 4 Normative data collection tasks and final word lists

4.1 Introduction to the normative data collection

The initial stimuli selected by the researcher for the draft word lists included 50 targets and 50 partners in each experimental semantic task, plus 50 phonological distractors and 50 unrelated distractors in the WPM task, which then entered a normative phase which is described here. In choosing the target stimuli the researcher considered the need for matching for word frequency, imageability and word length between tasks, and appropriate semantically similar or associated primes or distractor pairs. Within the WPM task, unrelated distractors were identified with similar frequency, imageability and length ratings as their target partner. Phonologically related distractors similar in frequency and length were identified, however due to the limitations of selecting phonologically similar words, it was not possible to also control for the variable of imageability within this category.

Before the final matching analyses could take place, further data needed to be collected to assess the suitability of the items chosen by the researcher. Normative data were subsequently collected for three additional variables, where values were not available through other sources, including:

i. Semantic similarity between partner-target pairs;
ii. Visual similarity between partner-target pairs;
iii. Name agreement for all stimuli appearing as images (all items in WPM, target items in WPV).

These dimensions were measured via a semantic similarity rating task (SST), a visual similarity rating task (VST) and a name agreement task, respectively. At certain points during the data collection phase additional items had to be added due to difficulties with stimuli, which will be outlined in the following chapter.

4.2 Participants

Separate groups of control adult participants were recruited to each of the three normative data collection tasks; their demographics will be presented in relation to each task. Firstly, the methods and results of the two rating tasks will be presented, followed by the methods and results of the name agreement task. The participant criteria presented within the current section is applicable to all three tasks.

4.2.1 Ethical approval and recruitment

Ethical approval was granted by The University of Sheffield Department of Human Communication Sciences Research Ethics Committee. Participants were recruited via opportunistic sampling methods via social networks.

4.2.2 Criteria for inclusion and exclusion

The inclusion and exclusion criteria for all participants were as follows:

- Age 18 and over;
- Monolingual literate native English speakers;
- No history of speech, language or literacy impairment;
- No history of neurological disease;
- Sufficient visual acuity (aided or unaided) to enable accurate reading of written text (rating tasks) and processing of images on a computer screen (name agreement task).

4.2.3 Consent and ethics approval for the study

All participants were provided with a research information sheet (see Appendix B) and were given the opportunity to ask questions. The information sheet included information regarding consent, the right to withdraw, anonymity, and storage of data.

For the rating tasks, after reading the information sheet, participants were given the option of either discontinuing or commencing the task. At the start of the rating task the research information sheet was summarised in a series of statements. By reading the project information and continuing with the rating task, participants were aware that they were opting in and giving informed consent to proceed in line with the research statements. The ethics committee approved this form of consent rather than written consent for the rating tasks. For the name agreement task, participants provided informed written consent to participate and gave permission for audio recordings to be made and securely stored.

4.3 Ratings of semantic relatedness and visual similarity

Two rating tasks were developed; a *semantic similarity rating task* and a *visual similarity rating task.* Both rating tasks consisted of 250 pairs of written single words. A group of participants were recruited, and their allocation to one task (SST or VST) was pseudo-randomised. Each pair of stimuli entering the final lists had been rated by twenty participants for semantic and visual similarity. Instructions and examples for both rating tasks are presented in Appendix C.

4.3.1 The semantic similarity rating task materials

The *semantic similarity rating task* (SST) was used to ascertain the perceived semantic similarity between the partner and target word pairs, as previously identified by the researcher.

For the SST, participants were presented with 250 pairs of written words and asked to rate their similarity on a numerical point on a 1-9 visual rating scale, 1 being not similar in meaning, 5 being moderately similar in meaning, 9 being highly similar in meaning. This design was based on similar rating scales used to evaluate the semantic relatedness of items in an existing semantic priming study (Moss et al., 1995) and in a critique of items in a WPM test (Cole-Virtue & Nickels, 2004a).

The task included all word pairs that had been preliminarily allocated to the experimental semantic tasks, including semantic and associative prime-target pairs for the SP task (*n* = 50), and semantic and associative distractor-target pairs for the WPV task (*n* = 50) and WPM task (*n* = 50). Of the 150 pairs of stimuli, the researcher had classified 96 pairs as being semantically similar with low association, and 54 pairs as being associated and not semantically similar, as per the Edinburgh Association Thesaurus norms (for association data see final word lists in Appendix A). The rating task also included 100 additional pairs of stimuli, including the phonological (*n* = 50) and unrelated distractors (*n* = 50) from the WPM task paired with their WPM targets which were predicted to have no or very low semantic or associative relationships.

4.3.2 The visual similarity rating task materials

The *visual similarity rating task* (VST) was used to evaluate visual similarity between 150 stimuli pairs used in the WPM task (the only task where more than one image appeared simultaneously). For the VST, participants were presented with 250 pairs of written words and asked to consider the similarity in appearance of the two objects in each pair and rate them on a 1-9 visual rating scale, 1 as not visually similar, 5 as moderately visually similar, and 9 as highly visually similar.

Word pairs intended for use in the WPM task were rated, including target words and semantic or associative distractors (*n* = 50), targets (*n* = 50) and phonological distractors (*n* = 50), and targets (*n* = 50) and unrelated distractors (*n* = 50); a total set of 150 pairs of images. Additional items (*n* = 100) were also rated in case some items were not acceptable and needed to be substituted due to high visual similarity ratings. Additional data were collected where ratings were unacceptable and a target had to be allocated a new partner.

4.3.3 Rating task design

Pseudo-randomisation within the rating task word list was achieved by distributing phonological pairs (*n* = 50) and unrelated pairs (*n* = 50) throughout the semantically similar pairs (*n* = 96), and associated pairs (*n* = 54) to ensure that there were no more than three consecutive instances of the same category of stimuli pair relationship. Targets from the WPM task appeared in each rating task three times (with their semantic or associative, phonological and unrelated distractor) and each instance of each target was separated by a minimum of 10 intervening items.

Presentation of stimuli was pseudo-randomised to control for order effects including fatigue and practice. In each rating task the 250 stimuli pairs were split into four blocks (two blocks with 63 pairs and two with 64 pairs), labelled A, B C and D, and the order of stimuli pairs within each block was randomised. There were four orders of presentation of the four blocks (ABCD, BCDA, CDAB and DABC).

4.3.4 Participant summary

Forty participants were recruited to complete either the SST or the VST. Forty additional participants were recruited to rate a subset of word pairs that had to be changed following the administration of the first rating tasks, due to unacceptably high visual similarity.[6] The additional subset was rated completely separately to the first forty items. The sample size for the rating tasks was based on a review of two studies with similar experimental design (Moss et al, 1995; Cole-Virtue & Nickels, 2004a).

Twenty participants completed the SST (12 female, 8 male (P20)). Their ages ranged from 25-48 years (*M* = 32 years). A subset of 21 additional word pairs was completed by a separate group (11 female, 9 male (P20); age range 22-49 years, (*M* = 32 years)).

Twenty participants were recruited to complete the VST (12 female, 8 male (P20)). Their ages ranged from 26-40 years (*M* = 33 years). A subset of 18 word pairs were judged by a separate group (12 female, 8 male (P20)); age range 27-39 years, (*M* = 32 years).

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[6] Two items with the two highest visual similarity ratings were replaced. The target *arrow* and unrelated distractor *fork* were rated as 3.9 visually similar, thus *fork* was replaced with flag. The target *kennel* and phonologically related *tunnel* were rated as 4.2 visually similar, thus tunnel was replaced with *funnel*.

4.3.5 Procedure

Participants completed the rating tasks in one of two ways. They either attended the university clinic, where the researcher explained the task verbally, or they received an email with the project information and the relevant rating task, including instructions. Participants were given two practice items with explanations on the written information at the start of the tasks. For the SST this included one example of a pair deemed to be highly similar in meaning (*cod-haddock*) and one highly dissimilar (*cod-guitar*). The VST examples included one stimuli pair deemed to be highly visually similar (*ball-orange*) and one dissimilar (*ball-house*). For both tasks, participants were instructed to: not spend too much time considering each word pair, make their decisions independently, and complete the task in one sitting but with a break if needed. Participants had no further interaction with the researcher whilst completing the task except where participants queried the meaning of homographs, such as *wood*. Each task took approximately 20 minutes to complete, however there was no time limit for completion. Participants returned completed word lists to the researcher.

4.4 Semantic similarity ratings results

4.4.1 Planned analyses

Non-parametric analyses were completed as data were ordinal and the target-phonologically related and target-unrelated ratings were non-normally distributed. Between and within list comparisons were completed. Firstly, semantic and associative ratings were explored between experimental semantic tasks. Kruskal-Wallis Tests were carried out for between-list comparisons of the ratings for: i) semantically similar word pairs; ii) associated word pairs; and iii) the combined ratings for these two relationship types. Secondly, differences within-list were investigated. This included i) comparisons of semantic similarity ratings for semantically similar and associated stimuli within each task, using Mann-Whitney U tests; and ii) within the WPM task, comparison of semantically similar, associative, phonological and unrelated distractor target pair ratings, using the Kruskal-Wallis test. Post-hoc tests using Mann-Whitney U tests were subsequently completed for pairwise comparisons. A Bonferroni adjustment was applied (=.05/4) and the significance levels are reported at .0125. Two-tailed significance values are reported. See Appendix D for word pairs' mean ratings of semantic similarity for the experimental semantic tasks.

4.4.2 Between-task comparison of semantically similar and associated pairs

Table 4.1 displays the results of the between task comparison of semantic similarity ratings of targets and their semantic or associative partners, including comparison when semantic and associated words are considered as one overarching semantic group.

Table 4.1: Between-task comparison of target and semantic or associative word pairs

Target pair relationship	**Items per list**	**SP list median**	**WPV list median**	**WPM list median**	χ^2	*df*	*p*
Semantically similar	32	6.20	6.18	5.98	1.33	2	.515
Associated	18	3.95	4.00	3.73	3.19	2	.206
Semantically similar and associated combined	50	5.65	5.60	5.38	1.96	2	.366

Note. χ^2 = Kruskal-Wallis Test statistic; *df* = degrees of freedom, *p* = significance.

There was no significant difference in semantic similarity ratings between the three task word lists for any of the three target-distractor relationship categories: when the targets paired with semantically similar primes/distractors, associated primes/distractors, or when the semantically similar and associated categories were combined into one category. The experimental semantic tasks are therefore matched on semantic similarity between target and prime/distractor stimuli pairs.

4.4.3 Within-task comparison of semantically similar and associated pairs

Table 4.2 displays the comparison of semantically similar ratings for semantically similar and associated target pairs within task.

Table 4.2: Comparison of semantically similar and associated stimuli within task

Task	***U***	***z***	***p***	***r***
Semantic priming	29.50	-5.23	< .001***	.74
Word to picture verification	34.50	-5.13	< .001***	.72
Word to picture matching	28.00	-5.26	< .001***	.74

Note. U and *z* = Mann-Whitney U Test statistics, *p* = significance, *r* = effect size. ***p ≤ .001.

Within all word lists, semantic similarity ratings were significantly higher for semantically similar partner-target pairs than for associated partner-target pairs, with large effect sizes (Cohen, 1988).

Table 4.3 presents the medians of the semantically similar, associative, phonological and unrelated distractor-target pair ratings in the WPM task.

Table 4.3: Median semantic similarity ratings for target-distractor pairs in the WPM task

	Semantically similar / associated combined	**Semantically similar**	**Associated**	**Phonologically related**	**Unrelated**
Number	50	32	18	50	50
Median	5.38	5.98	3.73	1.10	1.05

Note. Rating scale: 1 = not similar in meaning, 5 = moderately similar in meaning, 9 = highly similar in meaning.

There was a significant difference in semantic similarity ratings between categories of distractor-target pairs in the WPM task, when the 50 targets in the overarching semantic-associated category were compared to the phonological and unrelated categories, χ^2 (2) = 103.78, *p* = <.000 and when considered in the four separate distractor categories (semantic, associated, phonological and unrelated), χ^2 (3) = 106.92, *p* = <.000. The results of the subsequent pairwise comparisons of semantic and associated categories versus phonological and unrelated categories are presented in Table 4.4.

Table 4.4: Semantic similarity pairwise comparisons between distractor-target categories in the WPM task

WPM distractor categories	***U***	***z***	***p***	***r***
Semantically similar pairs vs phonological pairs	.000	-7.63	< .001***	.84
Semantically similar pairs vs unrelated pairs	.000	-7.66	< .001***	.85
Associated pairs vs phonological pairs	.000	-6.29	< .001***	.76
Associated pairs vs unrelated pairs	.000	-6.34	< .001***	.77

Note. U and *z* = Mann-Whitney U Test statistics, *p* = significance, *r* = effect size.
***p ≤ .001.

Pairwise comparisons revealed significant differences in semantic similarity ratings between all the WPM distractor-target pair categories. Semantic similarity ratings for semantically similar and associated distractor-target pairs were significantly higher than both phonological and unrelated distractor-target pairs, with large effect sizes.

4.4.4 Reliability of the scale

The SSQ scale reliability was measured using Cronbach's alpha, within which values of .7 and .8 are deemed to be acceptable. When the three semantic experimental task word lists were combined, all scales had high reliability: when all semantically similar pairs were treated as one group (n=96) Cronbach's α = .98; when all associated pairs were treated as one group (n=54) Cronbach's α = .98. Reliability remained high when the semantically similar and associated categories were analysed in the three separate tasks. In the WPM task list phonological and unrelated pairs had high reliability also (see Table 4.5).

Table 4.5: Cronbach's α: scale reliability of experimental word lists

	SP task	WPV task	WPM task
Semantically similar pairs	.96	.92	.92
Associated pairs	.97	.96	.98
Phonologically related pairs	-	-	.89
Unrelated pairs	-	-	.72

4.4.5 Summary of semantic similarity rating task results

No significant differences in perceived semantic similarity were found between the three tasks for semantically similar partner-target pairs or associated-target pairs. The three experimental semantic tasks were therefore considered to be adequately matched in terms of semantic similarity of semantic or associated partner-target pairs.

Within each word list, semantically similar partner-target pairs were rated significantly more similar in meaning than associated pairs. Within the WPM task word list, both the semantically similar and associated prime-target pairs were perceived as more similar in meaning than phonologically related or unrelated distractor-target pairs. Both of these outcomes were predicted and integral to the experimental design.

4.5 Visual similarity rating task results

Data were collected on perceived visual similarity for pairs of stimuli used in all three word lists. Only data relating to the final word list used for the WPM task are presented; no images appear in the semantic priming task, and only single images appear in the WPV task. In instances where pairs resulted in high ratings, for example the instance of the target-phonological distractor *kennel-tunnel,* an alternative distractor *funnel* replaced *tunnel* after subsequent testing. The data reported here include the replacement stimuli and not the original items. Where new pairs were introduced they were also retested for semantic similarity ratings and the final sets are reported.

4.5.1 Planned analyses

Visual similarity ratings of stimuli pairs were compared within the WPM task only, including comparison of targets to all distractor types (semantic or associated, phonological and unrelated). As no images are present in the SP task, and only one image at a time in WPV, between-list comparison of degree of visual similarity was not indicated.

Non-parametric tests were used to compare the word categories within the WPM task due to the ordinal nature of the data and the non-normal distribution of the associated *D* (18) = .29, *p* <.001, phonological *D* (50) = .34, *p* <.001, and unrelated *D* (50) = .35, *p* <.001 word pair categories, as tested with the Kolmogorov-Smirnov test. Semantic and associative distractor-target pairs' visual similarity ratings were compared to phonological and unrelated pairs using a Kruskal-Wallis test. Post-hoc pairwise comparisons were subsequently completed. A Bonferroni adjustment was applied (=.05/5), and the significance levels are reported at .01. Two-tailed significance values are reported.

4.5.2 Within WPM task comparison of visual similarity ratings

Table 4.6 displays the median VST ratings for distractors in the WPM task. See Appendix D for individual word pair mean visual similarity ratings.

Table 4.6: Median visual similarity ratings target-distractor pairs in the WPM task

	Semantically similar / associated combined	**Semantically similar**	**Associated**	**Phonologically related**	**Unrelated**
Number	50	32	18	50	50
Median	3.60	4.93	1.25	1.08	1.05

Note. Rating scale: 1 = not visually similar, 5 = moderately visually similar, 9 = highly visually similar.

There was a significant difference in visual similarity ratings between categories of distractor-target pairs in the WPM task, when the 50 targets in the overarching semantic-associated category were compared to the phonological and unrelated categories, χ^2 (2) = 59.21, *p* < .001, and when considered in the four separate distractor categories of target-distractor pairs (semantic, associated, phonological and unrelated) χ^2 (3) = 76.91, *p* < .001. The results of the pairwise comparisons are presented in Table 4.7.

Table 4.7: Visual similarity comparisons between distractor-target categories in the WPM task

Distractor categories	***U***	***z***	***p***	***r***
Semantically similar vs associated pairs	17.00	-5.48	< .001**	.77
Semantically similar vs phonological pairs	21.50	-7.44	< .001**	.82
Semantically similar vs unrelated pairs	9.50	-7.56	< .001**	.83
Associated pairs vs phonological pairs	289.00	-2.27	.02	-
Associated pairs vs unrelated pairs	266.50	-2.59	.01*	.31

Note. *U* and *z* = Mann-Whitney U Test statistics, *p* = significance, *r* = effect size.
**p ≤ .001. *p ≤.01.

Semantically similar distractor-target pairs were rated more visually similar than associated, phonological and unrelated pairs, with large effect sizes. Associated distractor-target pairs were rated more visually similar than phonological and unrelated pairs, however with the adjusted alpha level this only reached significance for unrelated pairs, with a medium effect size (Cohen, 1988).

4.5.3 Summary

Within the WPM word list, the semantically similar distractor-target pairs were rated as significantly more visually similar than the other categories of associated, phonological and unrelated distractors. Associated items were also rated significantly more visually similar than unrelated pairs, but with a smaller effect size. It is proposed that this is due to semantically similar distractors sharing more visual feature overlap with their targets pairs than the associative, phonological or unrelated distractor-target pairs.

4.6 Name agreement

Name agreement has been shown to be a strong and robust predictor of picture naming in neurotypical populations and PWA (Alario, et al., 2004) and therefore was included in the current design as a stringent measure. However, the experimental semantic tasks did not involve spoken output, and instead only required pictures to be recognised in the presence of a written word. The ease with which items can be named could potentially affect their recognition time due to selection demands of multiple competing alternatives for items with low name agreement (Bose & Schafer, 2017). Name agreement was carried out for the images included in the WPV task (*n* = 50) and WPM task (*n* = 200). Normative naming responses were gathered to ascertain if each experimental image reliably depicted their corresponding lexical item. Due to the demands of the psycholinguistic matching it was necessary to include some items for which it was not possible to provide an unambiguous image of the concept, such as *food*, but for which the image was potentially acceptable as a valid portrayal of that concept. Hence for those items which were incorrectly named by a participant a word-picture verification task was completed.

4.6.1 Design

In the naming task each participant completed the total set of 250 images. Stimuli were blocked into five categories for presentation purposes, with 50 items in each block, including: target images appearing in the WPV task, and the four WPM categories of target, semantic or associative distractor, phonological distractor and unrelated distractor. The block of WPM target stimuli was separated in presentation from their semantic, associative and phonological partners as follows:

1. semantically similar or associated WPM distractors
2. WPV targets
3. WPM targets
4. unrelated WPM distractors
5. phonological distractors.

Presentation was pseudo-randomised with participants receiving one of five different orders of presentation, commencing the task at the beginning of one of the five blocks (ABCDE, BCDEA, CDEAB, DEABC, EABCD). Participant one was allocated the order of presentation beginning with set A, participant two with set B, and so on. Any items with a semantic relationship (e.g. two animal stimuli) or same initial phoneme were separated by three intervening items.

4.6.2 Participant summary

Twenty participants completed the name agreement task (11 female, 9 male). Their ages ranged from 22-49 years (*M* = 32 years). Additional naming data were gathered after the initial phase, as detailed in section 4.6.6.

4.6.3 Materials

The name agreement task was presented in the ResponseRecorder software program (M. Coleman Personal Communication, Department of Human Communication Sciences, UCL). Response recorder is a software programme that records spoken output into audio files, and naming latencies via manual mouse click to perceived voice onset. Images were presented in the same size as they would appear in their corresponding experimental semantic task; for WPV this was 550 x 350 pixels and for WPM 400 x 245 pixels, in both cases until one or both of the maximum diameters were reached.

Participant verbal responses were recorded on the laptop using an external Logitech microphone. The sessions were also recorded on a Beyerdynamic M 58 Omnidirectional

Dynamic Microphone attached to a Marantz PMD660 Portable Solid State Recorder. Recordings were made using a table top microphone stand with microphone placed within 0.5 metres of the participant's seated position.

4.6.4 Procedure

Each participant was assessed individually in a quiet room in their own home or in the communication clinic at the university. The testing was conducted in one session which lasted approximately 20 minutes.

Stimuli were presented consecutively on a laptop computer for participants to name. Participants sat approximately 50cms away from the screen. Each image appeared for a maximum of ten seconds. Participants were instructed to name each picture using just one word, the best single word that they could think of to describe the picture. Participants were told that they could self-correct, and were given a non-specific prompt if they did not name or self-correct to the correct response. The prompt was either "can you think of another word for it?" or "what else might it be?" The prompt was included to reflect the fact that this was name agreement for a comprehension rather than a naming task. For example if a participant named the target *mug* with a semantically acceptable target but undesired lexical form *cup,* an alternative was requested via a prompt to see if they could provide the alternative desired label.

The researcher was present throughout and controlled the presentation of the stimuli. When the participant began to name the item, the researcher recorded this by clicking the mouse key, which recorded the naming latency for that item to enable subsequent checks that responses had been made within 10 seconds. The researcher pressed a key which presented the next stimulus. If ten seconds elapsed without a participant naming an item, the researcher selected the next stimulus.

All participants completed a familiarisation phase of twelve practice items. If participants produced a response more than one word long, they were reminded that only one word responses should be given. For three WPV stimuli the part of the item to be named was highlighted with an arrow e.g. for the target *gravy* an arrow pointed to the content of the jug rather than the jug itself. Participants were alerted to this in the instructions and by means of three practice items with arrows. The subgroups of participants naming new images were presented with the same practice items as in the main name agreement task.

If participants did not name an item correctly following a prompt for an alternative word, after a short break a word to picture verification check was carried out for all items that were not correctly named. These stimuli were individually re-presented to the participant in question on the laptop screen, and the researcher named the target and the semantic or associative distractor in turn. Fifty percent of the time the target was named first, and 50% of the time the distractor was named first, which was pseudorandomised in situ. Participants were instructed to provide a verbal yes or no response to indicate whether the spoken words corresponded to the presented image.

4.6.5 Transcription and coding of responses

Responses were transcribed live by the researcher and scored as accurate or inaccurate. Responses were coded as correct when the intended lexical item was produced as a first response within ten seconds of the appearance of the picture, when the correct word appeared in the response (for example ‘ice skate’ for *skate* or ‘tennis racket’ for *racket*), and when participants self-corrected their initial response to either of the above response types within ten seconds.

Prompts for an alternative word, as described in section 4.6.4, were transcribed live and later coded in analysis. In the first tier of analysis, initial responses and self-corrections were used to calculate percentage name agreement. Correctly identified items following a prompt for an alternative word were included in the second tier of analysis. Picture verification accuracy formed a third tier of analysis.

4.6.6 Testing of new items

At later testing dates three subsets of participants completed name agreement for eight items that were exchanged with previous stimuli, summarised in Table 4.8.

Table 4.8: Participant details for additional items tested in name agreement

No. of new images	No. of participants	Sex	Mean age	Age range
2	18	10 female 8 male	32	22-49
5	16	9 female 7 male	32	22-49
1	10	5 female 5 male	32	24-49

Three stimuli were exchanged. Two items were duplicated so were removed from one task: *rope* appeared in the semantic priming task thus was removed as a distractor in WPM and replaced with *snow*; *pocket* appeared in the WPV task so was replaced in WPM with the phonological distractor *racket*. The phonological distractor *nappy* was replaced with *pumpkin*, as the target distractor pair *napkin-nappy* received a mean rating of 3.36 on the SST, which was above the mean of 1.25. These new stimuli were retested for name agreement, semantic similarity and visual similarity in the rating and naming retest phase.

In addition, five new images were tested and included in instances of low name agreement or where compound words were used for items, therefore alternative pictures were sought to provide more clarity in the WPM task. These items and rationale for inclusion of new images are presented in in Appendix F. Where replacement photos were introduced only the name agreement was retested, as the semantic and visual similarity values remained the same for the lexical item.

4.6.7 Name agreement results

Table 4.9 provides the results of name agreement accuracy. Tier one analysis contains the results of name agreement prior to prompting, i.e. first responses and self-corrections, and tier-two analysis provides the results with the addition of correct responses after the non-specific prompt was provided.

Table 4.9: Name agreement accuracy by stimuli type and task for final word sets

Category	**Tier one analysis (proportion accuracy)**	**Tier two analysis (proportion accuracy)**
WPV targets (50)	.94	.96
WPM targets (50)	.96	.98
WPM semantically similar / associated distractors (50)	.92	1.00
WPM phonological distractors (50)	.84	.90
WPM unrelated distractors (50)	.92	.96
Total	**.92**	**.96**

The ten items that did not reach >80% name agreement following a prompt for an alternative were correctly identified in the word to picture verification check, with 100% accuracy. Full name agreement accuracy by-item is presented in Appendix G.

4.6.8 Summary

The experimental semantic tasks involve single word lexical processing including word recognition (all tasks) and word comprehension (WPV and WPM) and do not require stimuli to be named, therefore a traditional name agreement task was not suitable. The methods used included naming and as required a follow-up non-specific prompt for an alternative word and a picture verification task.

Prompting for an alternative second response resulted in correct naming for items with two acceptable names. Prompting also elicited corrected responses for items with a lower frequency target name. For example *gift* was consistently named as *present*, but consistently renamed as *gift* when prompted. Visually similar items were often renamed correctly following a prompt, such as *frog* renamed as *toad*, *sea* renamed as *ocean* and *rock* renamed as *stone*, however a frequency effect may also have impacted in these instances. Low name agreement also resulted when superordinate categories were the target, for example the stimuli *meat*, where participants sometimes named the subordinate *beef*. In other instances the subordinate name was appropriate, for example the stimuli *sparrow* which was primarily named as *bird*.

Furthermore, the ten items which did not yield >80% name agreement following a prompt for an alternative, included stimuli that were unlikely to be named accurately from an image. These included five items from the WPM phonological distractor category which were included on the basis of phonological similarity to targets, for example, *glider* matched to *spider*, *possum* matched to *blossom, lotion* to *ocean*, and *copper* to *collar*. All of these lexical items were not easily identified from an image.

Taking these factors into consideration, some misnamed items were replaced, > 80% name agreement was achieved for the majority of final images, and those items with <80% name agreement but subsequent correct identification in picture verification were included in the experimental semantic tasks.

4.7 Stimuli matching for psycholinguistic variables

Following the data collection of the semantic and visual similarity ratings and name agreement, the word lists for each semantic experimental task were finalised. In this final chapter section, results of psycholinguistic matching are presented for the final experimental word lists. In section 4.7.1, frequency, imageability and word length (number of letters, phonemes and syllables) values are compared between the three semantic experimental tasks for both targets and semantically similar and associated partners, thus demonstrating psycholinguistic matching of variables for later comparison between the three tasks. Within the WPM task psycholinguistic matching of targets to phonologically related and unrelated distractors is considered in relation to frequency and imageability values.

4.7.1 Psycholinguistic variables: planned analysis

Between-task comparisons of target frequency, imageability and length variables were made using Kruskal-Wallis tests, to investigate the relative values across the tasks.

Within-task comparisons were made between targets, phonological and unrelated distractors in the WPM task, using Kruskal-Wallis tests. Phonological distractors were selected by the researcher primarily on shared phonological features rather than psycholinguistic matching. Unrelated distractor choice was constrained in that items could not be semantically or phonologically related to their target, and could not appear in the other experimental tasks. Secondary to these primary criteria, unrelated distractors were identified by the researcher that were similar in frequency and imageability to the target words with which they were presented, to support psycholinguistic matching of partner-target pairs.

4.7.1.1 Psycholinguistic matching: results

Comparisons of the key psycholinguistic variables between the three word lists are reported for targets in Table 4.10 and semantically similar or associated partners in Table 4.11.

Table 4.10: Between-list comparison of psycholinguistic variables for targets

Psycholinguistic variable	**SP list median**	**WPV list median**	**WPM list median**	**χ^2**	***df***	***p***
Frequency	10.52 (30.36)	10.44 (25.51)	10.68 (25.74)	.05	2	.97
Imageability	595 (22.83)	597 (19.94)	597 (19.77)	.55	2	.76
Letters	5 (1.49)	5 (1.54)	5 (1.48)	.16	2	.92
Phonemes	4 (1.41)	4 (1.41)	4 (1.51)	.37	2	.83
Syllables	1 (.61)	1 (.68)	1 (.65)	.33	2	.86

Note. Standard deviation in brackets.

Table 4.11: Between-list comparison of psycholinguistic variables for semantically similar and associated partners

Psycholinguistic variable	SP list median	WPV list median	WPM list median	χ^2	*df*	*p*
Frequency	6.38 (41.66)	5.58 (35.47)	9.95 (53.55)	.53	2	.77
Imageability	592 (39.97)	591 (37.94)	591 (31.56)	1.06	2	.59
Letters	5 (1.64)	5 (1.39)	5 (1.81)	.22	2	.90
Phonemes	4 (1.37)	4 (1.23)	4 (1.61)	.53	2	.77
Syllables	2 (.58)	2 (.63)	1.5 (.73)	.45	2	.80

Note. Standard deviation in brackets. Imageability values were only available for 104/150 semantically similar and associated stimuli, including 37 in SP, 31 in WPV and 35 in WPM.

When comparing across the three word lists, the data demonstrate that there are no significant differences in frequency, imageability or length for target words or for semantically similar and associated partners. Table 4.12 presents the comparisons of psycholinguistic variables for the phonological and unrelated distractors in the WPM task.

Table 4.12: Within-list comparisons for phonological and unrelated stimuli psycholinguistic variables in the WPM task

Psycholinguistic variable	WPM target median	WPM phonological median	WPM unrelated median	χ^2	*df*	*p*
Frequency	10.68 (25.74)	10.44 (63.95)	9.47 (22.55)	.33	2	.85
Imageability	597 (19.77)	584 (40.74)	592 (27.61)	5.61	2	.06
Letters	5 (1.48)	5 (1.44)	4.5 (1.72)	.08	2	.96
Phonemes	4 (1.51)	4 (1.29)	4 (1.33)	.80	2	.67
Syllables	1 (0.65)	1 (0.58)	1 (0.65)	.29	2	.87

Note. Standard deviations in brackets. Imageability values were only available for 36/50 phonological distractors.

There were no significant differences in frequency, imageability or length between targets, phonological distractors, and unrelated distractors in the WPM task.

4.8 The final word lists

The final three words lists were implemented in the three experimental semantic tasks. Within each list there are 50 targets matched between the tasks on the psycholinguistic variables of frequency, imageability and length, each paired with a semantically similar or associated prime/distractor partner. Within each experimental semantic task, 32 of the target-partner pairs were semantically similar and 18 were associated. Semantic similarity of semantic or associative partner-target pairs was matched between the tasks.

Within the WPM task phonological distractors were chosen to share the same onset or rhyme with their target word, but were not semantically similar or associated. Unrelated distractor stimuli were not phonologically or semantically similar to the target. Neither phonological nor unrelated distractor-target pairs were perceived to be visually similar to targets, as demonstrated by results of the VST. Both phonological and unrelated distractor categories were matched in frequency, imageability, and length to WPM targets. Full details of the experimental semantic task stimuli, including item imageability, frequency, and association ratings can be found in Appendix A. Mean values for frequency and imageability for prime/target pairs in each task are also shown in Appendix A, Table A4.

Chapter 5 Methods: Semantic experimental tasks, language and cognitive testing

5.1 Overview

Performance on the three lexical semantic tasks was explored with two groups of participants: control participants and individuals with aphasia. This chapter outlines the methods used, and the results for each individual task are presented in Chapters 6, 7 and 8.

The three experimental semantic tasks comprised: a **Semantic Priming** (SP) task; a **written Word to Picture Verification** (WPV) task; and a **written Word to Picture Matching** (WPM) task. Data were collected from control participants, against which to evaluate the performance of the participants with aphasia (PWA).

Each participant completed all three tasks. There were two main differences in task completion between controls and PWA. In the SP task controls completed one list of SP stimuli and PWA completed both lists. In the WPV task controls completed one list and PWA completed two lists. Details of the design of both tasks are provided in the relevant sections below. The rationale for this was to allow for within-participant analyses for PWA within tasks. For WPM each target stimulus was seen once by all control participants and all individuals with aphasia.

Each PWA completed language and cognitive assessments in addition to the experimental semantic tasks (see section 5.6.1). A proportion of control participants completed some of the language and cognitive tasks where there were no available normative data.

This chapter outlines the methods and design of the experimental semantic tasks and details the additional language and cognitive testing that PWA completed.

5.2 Participants

5.2.1 Criteria for entry

The inclusion and exclusion criteria for all participants were as follows:

- Aged 40 and above[7];

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[7] A wide age range was recruited to capture the age range of older adults experiencing stroke, and thus the control group was matched in age to this. It is acknowledged that within the samples there is a potential impact of normal ageing on processing speed when considering response latency data and the semantic priming effect (Laver & Burke, 1993).

- Native speakers of British English;
- No previous history of speech, language, literacy or cognitive impairment ;
- No previous or co-morbid neurological or psychiatric conditions;
- No significant hearing loss;
- Sufficient visual acuity to process stimuli on a laptop computer;
- Sufficient attention to complete the assessments;
- Sufficient upper limb motor ability to interact with external laptop switches and keys on a laptop keyboard.

5.2.2 Criteria for people with aphasia

Participants with aphasia also met additional inclusion and exclusion criteria:

- Minimum six months post-onset of a single left-hemisphere stroke;
- Present with aphasia as diagnosed by researcher and previous speech and language therapist;
- Not receiving impairment-based speech and language therapy during the period of study;
- Able to give informed consent.

Language and other criteria were applied to the PWA, which were assessed at the time of recruitment. This included the participants' ability to undertake written lexical decision tasks, their residual lexical semantic function, visual field function, and upper limb, vision and hearing capacity. These functions were assessed in order to ensure that the participants had the necessary motor and cognitive ability to complete the main experiments, and were able to easily operate external switches and keys on a laptop computer. In order to enter the study PWA had to reach criterion on the tasks outlined in Table 5.1.

Table 5.1: Summary of the additional inclusion criteria for PWA

Skill or deficit	Assessment	Inclusion criteria
Visual neglect	CAT 1 line bisection	Within normal range (cut off ≥ 2.5)
Visual lexical decision	Subset of PALPA 25 written lexical decision on laptop	21/28
Visual/motor skills	Word to picture matching on laptop	7/10
Single word auditory comprehension	CAT 7 spoken word to picture matching	6/15
Single word written comprehension	CAT 8 written word to picture matching	6/15

Screening for visual neglect was completed with the CAT 1 Line Bisection (Swinburn et al., 2004); this was conducted in order to ensure that participants had the ability to process stimuli appearing on both sides of the computer screen in the experimental semantic tasks.

The ability to perform a lexical decision task and respond via button press was assessed using a subset of 28 items from the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA) Visual Lexical Decision subtest 25 (Kay et al., 1992). Fourteen high imageability words and 14 nonwords were presented via laptop computer and participants gave yes or no responses by pressing two external switches. The task demonstrated participants' ability to understand and perform a task that mirrored the format of the semantic priming task in the main experimental phase.

To ensure that participants had sufficient visual ability and motor skill to interact with the laptop and press the keyboard responses, a computer-delivered written word to picture matching test was created. The assessment included ten test items developed by the researcher, delivered with the aim of screening for motor and visual ability using the same layout, size of stimuli and laptop as in the experimental Word to Picture Matching task (see section 5.5.3 for task description). Participants matched a written word in the middle of the screen to one of four pictures appearing in each quadrant of the screen. Distractors were unrelated to the target word, with no semantic or phonological distractors included. Participants made their responses by pressing coloured keys on the keyboard that corresponded to the positions of the four images on the screen.

As written word reading is integral to performance on the main experimental semantic tasks, orthographic single word comprehension was assessed with CAT 8 written word to picture matching (Swinburn et al., 2004) to exclude individuals with significant impairment of accessing semantics via written words. CAT 7 spoken word to picture matching was also delivered so that comparison could be made across modalities.

A checklist was implemented detailing additional criteria that were informally measured, including the ability to sustain attention and switch between tasks, and to demonstrate adequate hearing, vision and auditory comprehension i.e. sufficient ability to follow task instructions.

At this stage pre-morbid handedness was also established. PWA were asked five questions regarding the hand or leg they would have used to complete particular actions prior to their stroke, including throwing a ball, brushing their teeth, opening a jar, writing, and kicking a ball. Participants scored 1 for every right-handed response, -1 for every left handed response, and 0 if either hand/foot was used. These scores were combined and resulted in the categories of pure left handed (-5), mixed left handed (-4 to -1), ambidextrous (0), mixed right handed 1-4, pure right handed (5). This scoring system is based on the Edinburgh Handedness Inventory (Oldfield, 1971).

5.2.3 Ethics recruitment and consent

Ethical approval for the project was obtained from The University of Sheffield Department of Human Communication Sciences Research Ethics Committee (see Appendix H). All participants were provided with approved information sheets. Accessible information sheets and consent forms were provided for PWA.

Control participants were recruited from South Yorkshire and the East Midlands using opportunistic sampling methods via social networks. Information about the study was disseminated by word of mouth, email and information flyers, and individuals contacted the researcher via phone or email if they met the criteria and wished to participate. Both female and male participants were recruited, with an aim to obtain approximately 50% of each. Information sheets were provided and participants were provided with the opportunity to clarify any issues directly with the researcher, prior to giving informed written consent to participate. Control participant information sheets and consent forms can be viewed in Appendix I.

Participants with aphasia were recruited via the local voluntary sector communication groups, a local independent stroke support group, and The University of Sheffield Department of Human Communication Sciences Aphasia Communication and Research Centre.

The researcher attended the groups and discussed the research with individuals using accessible information sheets for PWA. Individuals who were interested in taking part informed the researcher or group leader and contact details were either provided by the individual or, with permission, by partners, relatives, or the group leader. The researcher then made contact with the participant or participant proxy, and arranged to meet them individually to ascertain whether they met the criteria.

The recruitment involved an individual interview and a set of language and other assessments detailed in Table 5.1. The interview involved questions regarding employment, education, aetiology and date of stroke. This took place either in the University of Sheffield Philippa

Cottam Communication Clinic in the Department of Human Communication Sciences or in the person's home. Where requested, information sheets were also provided to partners/relatives who were invited to attend the recruitment session. Individuals with aphasia who met the criteria and who expressed a willingness to participate were then facilitated in the process of providing informed consent. Information and consent forms for PWA can be viewed in Appendix J.

5.2.4 Control participants: summary

Forty-one control participants were initially recruited (23 female, 18 male). One participant who met the inclusion criteria and who entered the main experiment, made a large number of errors in the semantic priming task and his data were deemed exceptional in comparison to the rest of the control group. As a result he was then eliminated from the study. Forty participants were therefore ultimately included. Full individual control participant demographics can be found in Appendix K. The final control group therefore consisted of 23 females and 17 males, of whom 34 were right hand dominant and 6 left hand dominant. Handedness was determined by observation of which hand participants used to write and to press the switches during the subsequent experiments. One exception to this was participant 6 who is categorised as right-handed - they used their left hand to write but were right dominant for button presses in the experiment. Table 5.2 displays the data for participants' age and education.

Table 5.2: Summary of control participant demographics (*n* = 40)

	Mean	Standard deviation	Range
Age (years)	63	8.26	41-81
Basic schooling (years)	10.83	.38	10-11
Enhanced schooling (years)	1.43	.84	0-2
Post-18 undergraduate (years)	1.78	1.48	0-3
Postgraduate (years)	0	.81	0-2
Education (years)	14	2.87	10-18

5.2.5 Participants with aphasia: summary

Twenty-four PWA underwent screening for inclusion, of whom 20 fulfilled the specified criteria and entered the main experimental phase. Two participants did not satisfy the exclusion criteria and their participation was terminated. One participant had an additional diagnosis of dementia, and one participant was not a native speaker of British English. Two further participants entered the main study but did not complete all the stages. One participant's health deteriorated, affecting her ability to engage with the computerised tests and manage task demands. A further participant died during the study. The main experimental dataset therefore includes 20 PWA.

Six female and 14 male PWA took part, of whom 19 were right hand dominant and 1 was left hand dominant. Table 5.3 shows the data for participants' age and education.

Table 5.3: Summary of PWA demographics

	Mean	Standard deviation	Range
Age (years)	66	8.82	46-84
Basic schooling (years)	10.3	.57	9-11
Enhanced schooling (years)	.85	.99	0-2
Post-18 undergraduate (years)	.75	1.33	0-3
Postgraduate (years)	.15	.49	0-2
Education (years)	12	2.68	9-18

The data from the recruitment interview are summarised in Table 5.4 along with the broad categorisation of fluency of spoken language.

Table 5.4: Demographics of PWA

Participant	Age	Sex	Years in education	Employment background	Time post stroke (years; months)	Premorbid handedness score	Premorbid handedness	Fluency
BT	79	M	16	Teacher	13;02	5	pure right	F
CW	70	F	18	Researcher; administration	4;07	5	pure right	F
DB	46	M	11	Manual worker	7;07	3	mixed right	F
DH	63	M	13	Engineer	1;04	5	pure right	NF
DW	69	M	10	Manual worker	6;07	5	pure right	F
FM	75	F	12	Professional	12;07	5	pure right	F
GB	64	M	12	Engineer; retail	4;09	5	pure right	F
JC	66	M	10	Manual worker; retail	4;01	5	pure right	NF
JK	64	M	10	Manual worker	3;10	3	mixed right	F
JM	84	F	9	Manual worker	5;05	1	mixed right	NF
LW	67	M	10	Manual worker	0;09	2	mixed right	NF
NMH	70	M	11	Professional administration	6;08	3	mixed right	F
PG	70	M	10	Manual and trade	5;07	5	pure right	F
PS	69	F	10	Manual worker	11;00	3	mixed right	F
RP	60	M	15	Professional	8;10	5	pure right	F
RT	67	M	10	Professional administration	4;00	5	pure right	F
SE	69	M	12	Manual worker	9;06	-1	mixed left	F
SH	52	F	16	Professional administration	18;07	5	pure right	NF
SL	63	F	10	Retail	4;02	3	mixed right	NF
TS	53	M	16	Professional	7;10	5	pure right	F

5.3 Design

5.3.1 Design of the study

The study involved two parallel groups who completed all three tasks. This provided a comparison of the control group versus the aphasia group performance on the three experimental semantic tasks. There is *between-group* comparison of control participants versus PWA on all three experimental semantic tasks and *within-group* comparisons across tasks for control participants and for PWA independently.

In the SP task, control participants completed either the related or the unrelated condition for each target stimulus. In the WPV task they completed either the congruent or the incongruent condition for each target stimulus. In contrast the PWA completed all conditions for all stimuli. This allowed between-group comparisons for all tasks, within-participant comparisons of each individual with aphasia to controls, and allowed each PWA to act as their own control. For WPM all participants completed all test items.

In addition the PWA completed cognitive tests and speech and language tests to provide background information for the purpose of within-participant comparison of performance between the experimental semantic tasks and specific language and cognitive tasks. In addition to providing typical data for the experimental semantic tasks, the control group provided normative data for the Towers of Hanoi cognitive assessment and measures of word and nonword reading and repetition to allow for group comparisons.

5.3.2 Design of the word lists

Each task included 50 sets of semantically related word pairs which had been matched for all significant variables across the sets (details in Chapters 3 and 4). Within the 50 word pairs there were more semantically similar than associated pairs; each set included 32 semantically similar word pairs (e.g. *potato-onion*) and 18 semantically associated word pairs (e.g. *porridge-spoon*). The SP and WPM tasks also included 50 semantically and phonologically unrelated words. The WPM task also included 50 phonologically related semantically unrelated words.

For the SP task the related words acted as primes and the unrelated words acted as the control condition for the prime-target pairs. For example, the design would then allow comparison of reaction times to *dog* for the unrelated condition *fork-dog* and the related condition *cat-dog*.

For the WPM task the semantically related, the phonologically related and the unrelated words all acted as distractors in an array.

5.3.3 Participant completion of tasks

Each control participant completed one word list for the SP task, one word list for the WPV task and the complete set of stimuli for the WPM task. For the SP and WPV tasks participants were randomly allocated a word list, with the proviso that 50% completed one list and 50% completed the second list. All participants completed the SP task first, then WPV and finally WPM. The SP task was administered first to avoid contamination from stimuli in the other semantic tasks; this was followed by WPV to enable the first part of the task to be spaced as far as possible from the second part for PWA. The order of presentation was standardised across participants, whilst acknowledging that this could potentially have implications in terms of either fatigue or reduced response latencies in the later tasks due to increased familiarisation in interacting with the task equipment.

Each PWA completed two word lists for the SP task, at least six months apart in time (*M* = 188 days, *Ra* = 182-200 days). Half of the PWA completed list 1 first, and half completed list 2 first, with pseudo-random allocation to order, with the proviso that 50% of participants completed one order and 50% completed the second order. Each PWA completed both assessment sets for the WPV task, at least 25 days apart in time (*M* = 66, *Ra* = 25-96). In the WPV task, half the PWA completed set 1 first, and half completed set two first, with pseudo-random allocation to order, with the proviso that 50% of participants completed one order and 50% completed the second order. All participants completed the full WPM task once.

It was necessary to have a longer time gap between completion of word lists for the SP task compared to WPV to eliminate the potential effects of repetition priming which can be long-lasting. A shorter time between testing was appropriate for WPV as the task is measuring semantic processing, control and decision making, and arguably priming is not a factor. PWA completed the SP task (one list), the WPV task (one list) and the WPM task, in that order. At the end of the testing phase each PWA completed the second of their WPV sets. A single final session occurred a minimum of six months after the first session, in which participants completed the second of their SP word lists. The time frame of the testing period for each PWA can be viewed in Appendix L.

5.4 Overall procedure

After providing the necessary recruitment information and providing informed consent, each participant attended one session (controls) or a series of sessions (PWA) where they completed the three semantic tasks, and other language and cognitive assessments. All participants were seen individually by the researcher in a quiet room either in the University or in their own home.

Each control participant completed one assessment session, lasting between 45 minutes and one hour. This included the process of providing informed consent, and completion of the three experimental semantic tasks. A subset of control participants then completed some additional tests for which no or inadequate control data existed. These were as follows: 21 participants completed the Towers of Hanoi (Simon, 1975), 10 completed word and nonword repetition tasks, and 10 completed word and nonword reading aloud tasks.

In their main testing block PWA completed between four and seven assessment sessions, one session per week. In these sessions they completed the three semantic experimental tasks and the language and cognitive tests. In the first session they completed the first list of the SP task, and the first set of the WPV task and the WPM task. In subsequent sessions they completed the language and cognitive tasks. The amount of assessment completed within each session was flexible according to each participant's ability and needs. Breaks were taken as required and sessions lasted between one and two hours.

5.5 Experimental semantic tasks

All three experimental semantic tasks were generated and presented using PsychoPy (Peirce, 2007), which presented the stimuli on a laptop computer, and which also recorded accuracy and reaction times of responses. Participants sat approximately 50cms away from the screen. In selecting a response choice control participants used their dominant hand, and PWA used the hand with which they had most motor dexterity.

5.5.1 Experimental task one: semantic priming

The SP task involved visual lexical decisions, with a continuous list presentation which required lexical decision to all stimuli appearing in the list[8]. The complete set of stimuli included: 50 target words appearing in the related condition i.e. preceded immediately by their related word partner (*cat-dog*); the same 50 target words in the unrelated condition i.e. preceded immediately by their unrelated word partner (*fork-dog*). There were also 25 filler words and

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[8] As discussed in Chapter 2, auditory and pairwise list presentation has also been investigated in PWA, however use of continuous list presentation is thought to reduce strategic processing of the stimuli. It is reported that more robust priming effects have been found using visual list presentation of stimuli as opposed to paired lexical decision presentation in PWA (Del Toro, 2000).

125 nonwords. See Chapter 4 for details of matching of primes and targets. The full word list for the SP task is presented in Table A1 in Appendix A.

5.5.1.1 List design

The 50 prime-target pairs in each of the two conditions of related and unrelated pairs of stimuli were split into two lists. The first list contained targets 1-25 in the primed condition i.e. with their related prime partner, and targets 26-50 in the unprimed condition i.e. with their unrelated prime partner. This pattern was reversed in the second list. Hence each target appeared once only in each list. Sixteen of the semantically similar prime-target pairs and nine of the semantically associated prime-target pairs were assigned to each list. Each list contained the same 125 nonwords and 25 fillers. There were therefore a total of 125 words and 125 nonwords in each list.

Semantic priming list 1 and list 2 were matched for both prime and target frequency and imageability. Independent Mann-Whitney U tests were conducted to compare target frequency and imageability between lists. For targets, no significant difference was found in frequency between SP list 1 (*Md* = 17.33, *n* = 25) and list 2 (*Md* = 9.12, *n* = 25), *U* = 282, *z* = -.59, *p* = .56, and no significant difference in imageability was found between SP list 1 (*Md* = 595, *n* = 25) and list 2 (*Md* = 590, *n* = 25), *U* = 281.50, *z* = -.60, *p* = .55. For primes, no significant difference was found in frequency between SP list 1 (*Md* = 6.30, *n* = 25) and list 2 (*Md* = 6.46, *n* = 25), *U* = 292, *z* = -3.98, *p* = .70, and no significant difference in imageability was found between SP list 1 (*Md* = 610, *n* = 21) and list 2 (*Md* = 578, *n* = 16), *U* = 110, *z* = -1.78, *p* = .08.[9] Mean ratings for psycholinguistic variables of each word list can be viewed in Table M1 in Appendix M.

5.5.1.2 Filler words

Twenty-five filler words were included. Filler words were chosen that were neither semantic coordinates nor had any association to targets within the list of 50 target words. Fillers were matched in frequency and length to target items. The same filler words appeared in both lists. Twenty-five words were needed in order to ensure a low relatedness proportion (RP) of 0.2 within each ultimate list; the relatedness proportion is calculated by dividing the number of semantically similar or associated real word prime-target partners by the total number of test stimuli i.e. 50/250.

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[9] The comparison of imageability between lists 1 and 2 was approaching significance, however it should be noted that imageability ratings were not available for four items in list 1 and nine items in list 2. In addition, the primary objective was to ensure matching of targets between lists, and this was achieved.

5.5.1.3 Nonwords

In semantic priming methodology a word to nonword proportion of 0.5 is advocated (McNamara, 2005). Half of all correct responses to lexical decisions are required to be *yes* and half *no,* therefore 125 nonwords were included in each list. Nonwords were created by choosing 125 real words that were matched in length in syllables to the 125 real words in each list and changing one letter of each word. Identical nonwords appeared in both SP word lists. All nonwords had common English spellings (e.g. porge not porj) and pseudo-homophones were not included (e.g. cird as in lemon curd).

5.5.1.4 Selection and ordering of stimuli in lists

Within each SP word list the 250 stimuli were pseudo-randomised into five blocks of 50 items labelled ABCDE. The order of presentation of the blocks was pseudo-randomised across participants, such that the first participant began the task with block A, the second participant with block B, and so on. Within each block there were five related prime-target pairs, including semantically similar and associated pairs, five unrelated prime-target pairs, five fillers, and an equal number of words and nonwords.

To ensure that any given semantic sub-category such as animals did not all appear in the same prime condition in a list, semantic sub-categories of items in related and unrelated prime conditions were distributed across the two lists. Distribution of semantic sub-categories was also considered across blocks within the two lists, to ensure that targets of the same semantic sub-category were presented in separate blocks.

No more than three words or nonwords appeared consecutively. Phonologically similar items were separated ensuring that items with the same initial phoneme did not appear consecutively. Semantically similar or associated prime-target pairs were separated from other prime-target pairs by a minimum of two stimuli, and unrelated pairs were separated by a minimum of one other stimulus.

5.5.1.5 Participant exposure to lists

Control participants completed one of the two word lists, therefore seeing half of all the targets in the primed condition and half in the unprimed condition. No control participant saw the same target twice. PWA each completed both word lists, on separate occasions, ultimately being exposed to all 50 targets in both conditions.

5.5.1.6 Task materials and presentation

The stimuli consisted of written words in lower case Arial font (sized to 1.9cm), presented in the middle of the laptop screen. Each word appeared centrally on the screen for a maximum of two seconds. There was an inter-stimulus interval (ISI) of 0ms, therefore as soon as a response was made or the two seconds passed the next item appeared immediately on the screen. If a participant made their selection of yes or no before the two seconds had elapsed the next word then appeared immediately.

5.5.1.7 Procedure

In order to familiarise participants with the SP task they were presented with a 20-item list comprising of words and nonwords taken from the PALPA 25 Written Lexical Decision subtest, printed on paper. These were presented in order to explain the lexical decision task, without the added complexity of interacting with the laptop or speeded presentation.

Then participants were presented with practice items on the laptop. There were 20 practice stimuli, which were also items taken from the PALPA 25. Instructions appeared on the screen prior to the items:

You will see some words

If they are REAL press ✓

If they are NOT REAL press x

These were supported with verbal instructions provided by the researcher which were as follows: “Words will appear on the screen. You have to decide if each one is a real word, or a made up nonsense word. Press the tick if they are real words and press the cross if they are not real words. You only need to press the buttons gently, like this *(demonstrated)*. You can only use one hand. Which would you prefer to use? *(Participant responds).* You need to rest it on the table in the middle of the buttons. You have two seconds to respond before the next word appears. This may sound quick but it should be enough time to respond. There are five sets of 50 words and you can rest in between each set. There are some practice items first. Try to respond as quickly but as accurately as you can, if you miss a word or make a mistake it doesn’t matter; don’t stop, just carry on[10].”

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[10] The three experimental semantic tasks were piloted with two control participants and one PWA. This instruction was included following piloting of the SP experiment, as when pilot participants made errors they often paused and wanted to discuss the error, therefore missing responses to subsequent stimuli that continued to appear.

Participants were informed that their reaction times and accuracy would be recorded but they were not made aware of the experimental aims. After the practice block was completed participants carried out the main SP task. Participants were given the chance to rest between each block of stimuli.

Participants with aphasia followed the same task familiarisation with the 20 item list of words and nonwords presented on paper. Subsequently they were exposed to 30 practice items on the laptop. This included the same 20 items that the control participants saw, preceded by an extra set of 10 items which consisted of four real words interspersed with six nonwords containing atypical combinations of English orthographic letter strings. These additional items were intended to support participants' understanding of the task. All 30 practice items were presented twice: firstly at a slightly slower pace to the main experiment (500ms ISI); then secondly at the same speed at which they would appear in the main experiment (0ms ISI)[11]. Participants with aphasia were given the chance to repeat their 0ms practice block and two participants (JM and PG) took this opportunity because of the number of errors they had made.

For the practice items and the main SP experimental task the same written instructions appeared on the screen as for the control participants and adapted accessible verbal instructions were provided. The instruction regarding responding in a limited time frame was excluded as was instruction regarding hand-choice; this was handled individually for each PWA who may not have been able to use one hand due to hemiplegia.

The procedure was the same for PWA as controls, with two exceptions: there was a compulsory break between blocks of minimum five seconds; and PWA were given unlimited time to respond to each stimulus, as PWA typically take longer to make lexical decisions compared to unimpaired controls (Nickels & Cole-Virtue, 2004). The ISI remained at 0ms to reduce the likelihood of strategic processing. Therefore each stimulus remained on the screen until the PWA made a yes or no response, and then the next stimulus immediately appeared on the screen.

All participants were aware that they needed to pay attention to the screen for the 50 item blocks of stimuli, despite any unplanned external distractions such as noise from outside. If participants demonstrated momentary lapses in attention, their attention was refocused by a verbal prompt from the researcher.

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[11] During piloting of the experiment it was observed that the PWA required a practice to understand the task, and then a further practice to become accustomed to the speed of the decisions.

5.5.1.8 Recording responses

Responses were made using two Buddy Button switches (Smartbox$^{TM)}$ to provide accessible response options for participants with post-stroke upper limb hemiplegia. Switch use was supported using Sensory Software Switch Driver 6 and a Joycable 2 adaptor. Participants pressed a switch for either a *yes* or *no* response, represented by one green tick symbol and one red cross symbol adhered to the top of the switches. The *yes* response switch always appeared on the left and the *no* response switch on the right. Participants were instructed to use their dominant hand and began each block of stimuli with their hand resting on the table between the two switches. Participants clicked the relevant switch to signal yes or no.

There was one instance of the computer program freezing on one stimulus, otherwise no errors occurred with the program. In this instance the PWA had to pause for a few seconds until the sequence started again.

5.5.2 Experimental task two: written word to picture verification

The WPV task involved the 50 targets presented in two conditions: a congruent condition, where the image was presented with the target word, and an incongruent condition where the image was presented with the semantically related partner word (e.g. image of dog presented with the word cat). Participants were asked to indicate yes or no to signal the accuracy of the word and picture match. The word set constructed for the WPV task is presented in Table A2 in Appendix A.

5.5.2.1 Design

The 50 congruent and 50 incongruent pairs were split into two sets to make two lists. In list 1, 25 target pictures appeared with a congruent written word, and 25 appeared with an incongruent written word. In list 2 the opposite pattern occurred i.e. targets that were presented with an incongruent distractor in list 1 were presented with a congruent word in list 2 and vice versa. Each target appeared once in each list. There were equal numbers of semantically similar and associated pairs in each list.

Independent Mann-Whitney U tests were conducted to compare both frequency and imageability between lists for distractors and targets. Word to Picture Verification list 1 and list 2 were matched for both distractor and target frequency and imageability. Note that not all distractors had imageability ratings, therefore fewer items were included in these comparisons. For distractors, no significant difference was found in frequency between WPV list 1 (*Md* = 3.57, *n* = 25) and list 2 (*Md* = 12.26, *n* = 25), *U* = 233, *z* = -1.54, *p* = .13, and no significant difference in imageability was found between WPV list 1 (*Md* = 577, *n* = 16) and list 2 (*Md* = 597, *n* = 15), *U* = 108, *z* = -.49, *p* = .63. For targets, no significant difference was found in frequency between WPV list 1 (*Md* = 7.96, *n* = 25) and list 2 (*Md* = 11.36, *n* = 25), *U* = 248, *z* = -1.25, *p* = .22, and no significant difference in imageability was found between WPV list 1 (*Md* = 601, *n* = 25) and list 2 (*Md* = 595, *n* = 25), *U* = 270, *z* = -.83, *p* = .42. Mean ratings for psycholinguistic variables of each word list can be viewed in Table M2 in Appendix M.

5.5.2.2 Ordering of stimuli within lists

The 50 targets were randomised within each list and then scrutinised to ensure that: i) there was a maximum of three consecutive yes or no responses, ii) for incongruent items there was a maximum of three consecutive semantically similar or associated items, iii) no two consecutive targets shared the same initial phoneme, iv) no two consecutive targets were semantically related. Each set of 50 was split into two blocks of 25 items (A and B).

5.5.2.3 Exposure to lists

Control participants were exposed to one list only. Assignment to list was pseudo-randomised across controls, to ensure that 50% of the control participants viewed each list. Participants with aphasia saw both lists. Order of presentation of the lists to the PWA was randomised to ensure that approximately 10 PWA saw list 1 first and 10 PWA saw list 2 first. Within each list, order of exposure to the blocks was so that half saw A first and half saw B first.

5.5.2.4 Materials

The materials consisted of the two sets of the same 50 colour photographs with the exception of *lung*, *moon* and *triangle* for which colour digital images were used (described in Chapter 4), presented on a laptop computer. In one set an image appeared with its correct word, and in the other set the same image appeared with its semantically related partner word. Each image was paired with its matching written word in the congruent condition, and paired with its semantically similar (*n* = 32) or associated (*n* = 18) partner word in the incongruent condition. All images were sized to 550 x 350 pixels until one or both of the maximum diameters were reached. Written words were presented centrally at the top of the computer screen, and were in lower case Arial font (sized to 2.4cm).

5.5.2.5 Procedure

All participants completed a task familiarisation phase which consisted of four practice items: two different picture stimuli, each presented in a congruent and incongruent written word condition. These were presented on the computer screen and participants were shown how to select their response using the Buddy Button switches (Smartbox^{TM}). Participants then completed the main WPV task consisting of the two blocks of 25 test items. The instructions and test procedure were the same for practice and test items, and are detailed below.

Participants were given the following verbal instructions:
"You will see a word and a picture. Press the tick if they are the same, press the cross if they are different. You are trying to decide if the word and the picture are exactly the same, not just similar. You will have up to five seconds to respond to each one. There are some practice items first. Try to respond as quickly but as accurately as you can."

The verbal instructions were accompanied by written instructions that appeared on the screen, and were read aloud by the researched after the verbal instructions. The written instructions were as follows:

You will see a **word** and a **picture**
If they are the **SAME** press ✓
If they are **DIFFERENT** press x

For PWA the verbal instructions were presented accessibly i.e. with pausing, and explanations using short sentences. There was no time restriction on the responses of the participants with aphasia, and accordingly the instruction *"You will have up to five seconds to respond to each one"* was not included for these participants.

The task was presented as follows. For each trial the written word appeared centrally at the top of the computer screen, and 500ms after this the image appeared below in the centre of the screen. Control participants had five seconds to respond. If a participant did not respond within this timeframe the current image and word disappeared, and the next trial started, as above. There was a one second ISI between participant response and presentation of the next item, or between items where someone failed to respond and was timed out. Participants with aphasia had unlimited time in which to respond. There was a one second ISI between participant response and presentation of the next item for PWA as well. There were no instances where a PWA did not respond; if this had occurred the researcher would have intervened to move the task on to the next trial. There was a minimum break of two seconds after 25 items, however participants could pause for longer if they wished to. The task took approximately five minutes to complete for both groups.

5.5.3 Experimental task three: written word to picture matching

The third and final semantic task was a written Word to Picture Matching *(*WPM) task. This involved presentation of the target written word accompanied by four images. The images depicted the target, a semantically related distractor, a phonologically related distractor, and an unrelated distractor. The task was presented on computer screen and selection was made by use of the same laptop keys, adapted to accommodate the four choices available in the task. The word sets for this task can be viewed in Table A3 in Appendix A.

5.5.3.1 Design and ordering of stimuli within lists

Both groups of participants completed the WPM task once. This allowed for group comparison and case series within-participant comparison.

The order of targets was pseudo-randomised, then checked to ensure that no two consecutive targets shared the same onset or were semantically related. The set was divided into two blocks of 25 items (A and B). Block presentation was separately pseudo-randomised across the control participant and PWA groups so that half of each group saw block A first and half block B first.

The position of stimuli category was pseudo-randomised across quadrants of the screen, ensuring that the target or the same type of distractor did not appear in the same position on the screen for more than three consecutive trials.

5.5.3.2 Materials

The word sets for the WPM task consisted of the 50 target words and their corresponding distractors: 50 semantically related items distractors (32 semantically similar and 18 associated), 50 phonologically related items and 50 items unrelated either semantically or phonologically (described in Chapter 3). Unrelated items were matched for frequency and imageability to the target in the same array, confirmed by Mann-Whitney U tests. There was no significant difference in frequency between targets (Md = 10.68, n = 50) and unrelated distractors (Md = 9.47, n = 50), U = 1215.5, z = -.24, p = .81. There was no significant difference in imageability between targets (Md = 597, n = 50) and unrelated distractors (Md = 592, n = 50), U = 1064.5, z = -1.28, p = .20.

The picture stimuli in the WPM task were presented as colour digital photographic images, with the exception of *sun* and *rain*, which were represented by coloured line drawings. Due to the nature of the concepts, it was not possible to obtain photographs where *sun* and *rain* were clearly identifiable as the image focus, as other additional items or distracting backgrounds were present within the photographic images that were considered for suitability. Each image was sized to 400 x 245 pixels until one or both of the maximum diameters were reached.

Association between distractor items within each array (semantically similar or associated, phonologically related, unrelated) was measured using the Edinburgh Association Thesaurus to ensure that there was no association in either direction for combination pairs of these items within the array[12]. There was also no association bi-directionally between phonologically related or unrelated items and the target with which they appear[13]

The written word was presented centrally in lower case Arial font (sized to 1.9cm). For each trial the target, the semantic or associative distractor, the phonological distractor and the unrelated distractor each appeared in one of the four quadrants of the computer screen.

5.5.3.3 Procedure

Participants received written instructions on the screen supported with a verbal explanation of the task. The verbal instructions were as follows:

"You will see a word in the middle of the screen and four pictures, one in each corner, like this *(demonstrated using a diagram example of a word to picture matching task held up to the screen*). Each of these keys matches the position of a picture on the screen *(point to each)*. You need to choose the picture that matches the word. You will have up to five seconds to make your decision. Respond as quickly and as accurately as you can. There are some practice items first."

For PWA the sentence *"You will have up to five seconds to make your decision"* was not included.

The written instructions on the computer screen were as follows:

You will see four pictures on the screen
Read the word
Choose the picture that matches the word

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[12] Association ratings were not available for 8 phonological distractors (trampoline, glider, apron, salmon, skunk, possum, sleigh, pumpkin) and 2 unrelated distractors (harp, caravan).

[13] As discussed previously, the phonological distractor parrot to the target carrot had an association rating of 1, presumably due to phonological overlap. Association ratings were not available for 5 target to phonological or unrelated pairs (telescope, lobster, cannon, kennel, trolley), 8 phonological to target pairs and 2 unrelated to target pairs (as mentioned in footnote 8).

Both groups of participants completed a familiarisation phase of two practice trials on the computer prior to the main task.

Each written target word and the four images appeared simultaneously in all trials. There was an ISI of 1.5 seconds between items, and a minimum two second break after 25 items. Control participants had a maximum of five seconds to make their choice. The PWA group had unlimited time to respond.

Four coloured laptop keyboard keys represented each of the potential four responses. Keys (*e*, *i*, *x*, and *m*) were each covered with different coloured stickers and their position on the keyboard represented the position of the four quadrants of the screen. The keys were programmed to record responses to stimuli in the corresponding quadrant. Participants chose an image by pressing the corresponding key with their dominant hand.

5.6 Assessment of people with aphasia

Participants with aphasia completed language and cognitive tasks to generate individual profiles of language and cognitive ability. After the initial screening session each participant attended a further four to seven sessions to complete the full set of assessments, dependent on ability, availability and fatigue. The semantic tasks were included within these sessions. The assessments used are listed in Table 5.5.

Table 5.5: Cognitive and language testing for people with aphasia

Domain assessed	Assessment
Visual-perceptual skills	Line bisection[a] Symbol cancellation[b] Raven's Coloured Progressive Matrices[c] Dot counting[d] Position discrimination[d] Number location[d] Cube analysis[d]
Auditory attention	Elevator counting without distraction[e] Elevator counting with distraction[e]
Auditory short term memory	Digit span[f]
Phonological short term memory	Phoneme span[f]
Planning, self-monitoring, executive function	Trails test[b] The Brixton Spatial Anticipation Test[g] Towers of Hanoi[h]
Input speech processing	Phonological discrimination: minimal pairs[i] Auditory word recognition: auditory lexical decision[j] (PALPA 5)
Semantic processing	Comprehension of single spoken words[a] (CAT 7) Comprehension of single written words[a] (CAT 8) Auditory synonym judgement[j] j (PALPA 49) Written synonym judgement[j] (PALPA 50) Picture naming[a] Pyramid and Palm Trees test[k] Camel and Cactus test (pictures)[l] Picture Naming[l] Verbal Fluency within categories[l] Category Comprehension Test[l]
Phonological output	Word repetition[f] Word read aloud[f] Nonword repetition[f] Nonword read aloud[f] Oromotor screen (informal assessment)
Sentence processing	Comprehension of spoken sentences[a] (CAT 9) Comprehension of spoken sentences[a] (CAT 10) Cinderella story recall[f] Picture description[a] (CAT 19) Conversation sample

[a] CAT Comprehensive Aphasia Test, (Swinburn et al., 2004)
[b] CLQT Cognitive Linguistic Quick Test (Helm-Estabrooks, 2001)
[c] Raven's Coloured Progressive Matrices (Raven, 1956)
[d] VOSP Visual Object and Space Perception Battery (Warrington & James, 1991)
[e] TEA The Test of Everyday Attention (Robertson et al., 1994)
[f] Ruth Herbert, Personal Communication
[g] Burgess & Shallice, 1997
[h] Mike Coleman, Personal Communication
[i] ADA Action for Dysphasic Adults Comprehension Battery (Franklin, Turner, & Ellis, 1992)
[j] PALPA : Psycholinguistic assessments of language processing in aphasia (Kay et al., 1992)
[k] PPT Pyramids and Palm Trees test (Howard & Patterson, 1992)
[l] CSB Cambridge Semantic Battery (Bozeat, Lambon Ralph, Patterson, Garrard, & Hodges, 2000)

5.6.1 Cognitive assessment

One aim of the study was to compare the cognitive processing ability of PWA to their performance on the experimental semantic tasks. A range of cognitive tests was therefore included to encompass different aspects of cognitive processing, while keeping the assessment schedule manageable for participants.

5.6.1.1 Visual-perceptual skills

The visual neglect screen included tests of line bisection (CAT, Swinburn et al., 2004) and symbol cancellation (CLQT, Helm-Estabrooks, 2001). Visual spatial perception and nonverbal reasoning were assessed using the Coloured Progressive Matrices (Raven, 1956) which, as discussed in Chapter 1, is also often referred to as measure of executive function.

Four subtests of visual space perception and discrimination were included from the VOSP (Warrington & James, 1991). In the *dot counting* subtest, participants are required to count the number of black dots that appear in a cluster on a page, reported to screen for the ability to perform simple scanning and "impaired single point localisation (visual disorientation)" (Warrington & James, 1991, p.14). If participants demonstrate impairment at this task then they would likely struggle with more complex spatial tasks such as word to picture matching. *Position discrimination* assesses the ability to perceive the relative position of two dots in two-dimensional space (Warrington & James, 1991). Participants judge if the position of one black dot in a square is the same position as a black dot in a second square. *Number location* is a more challenging spatial task in which participants match the position of a number in one square to the position of a dot in a second square. *Cube analysis* assesses the capacity of participants to perceive three-dimensional space in a two-dimensional line drawing, by counting of the number of cubes joined together in a configuration. Any impairment in skills required for these tasks could impact on performance on the experimental semantic tasks and on other assessments.

5.6.1.2 Attention

Auditory sustained and divided attention were assessed using the two elevator counting subtests from The Test of Everyday Attention (Robertson et al., 1994). In the elevator counting test participants are required to count the number of auditory tones, and in the test with distraction participants count the low tones and ignore the newly introduced high tones.

5.6.1.3 Memory

Auditory short-term memory was assessed using a digit span task in which participants were asked to recall an increasing number of digits. The test begins with the repetition of a three digit span, and is followed by a further ten trials. If the digit string is repeated accurately and in the correct order then the subsequent trial is increased by one digit. If repeated unsuccessfully then task demands are decreased by removing one number from the digit span. The mean of the final ten trials is calculated. Phonological short-term memory was assessed using the same method but instead participants repeat consonant-schwa combinations. As success at both tasks requires speech output, performance on this task may be restricted for PWA.

5.6.1.4 Planning, self-monitoring and executive function

The Trails Test (CLQT, Helm-Estabrooks, 2001) assesses non-verbal executive function via participant ability to draw a line between alternate shapes of increasing size. Performance involves skills of sustained attention, fine motor control, visuospatial skills and visual perception, and executive functions of working memory, planning and cognitive flexibility. The subtest provides an informal insight into participants' problem-solving ability with reduced language demands, and provides cut-off scores for two age groups to demonstrate performance falling within or outside normal limits.

The Brixton Spatial Anticipation Test (Burgess & Shallice, 1997) assesses rule attainment and strategies used in response when rules change. Participants are presented with 10 circles, one of which is coloured and moves position as each page is turned, depending on a sequence or 'rule' that changes as the task continues. It provides insight into monitoring and detection of changes in sequence, response inhibition and non-verbal reasoning. It can be delivered more quickly and with fewer language demands than commonly used tests with similar objectives, such as the Wisconsin Card Sorting Test (Grant & Berg, 1948; 1993).

A computer-based Towers of Hanoi task was developed (M. Coleman, personal communication) to assess non-verbal reasoning and executive function. This was also completed by 21 control participants to provide normative data. Participants are presented with three poles of equal height, with discs of graduated size (smaller size ascending) on the left-hand pole. The task difficulty increases with the increase in number of discs from a minimum of two to a maximum of five discs. The aim of the task is to move the discs to the right-hand pole to finish in the same graduated size arrangement but whilst adhering to the following rules: only one disc can be moved at any one time; a larger disc cannot be placed on top of a smaller disc; only the disc at the top of a pile can be moved.

5.6.2 Speech and language assessment

A range of input and output language tasks was delivered including a variety of different semantic assessments to compare to performance on the experimental tasks.

5.6.2.1 Input processing

Phonological discrimination was assessed using the ADA minimal pairs test (Franklin et al., 1992). PALPA 5 Auditory Lexical Decision (Kay et al., 1992) was used to examine auditory word recognition, including the effects of imageability and frequency.

5.6.2.2 Semantic processing

Semantic processing was investigated using pictures, spoken words and written words in a range of assessments. CAT 7 Comprehension of Spoken Words and CAT 8 Comprehension of Written Words (Swinburn et al., 2004) were used to assess single word comprehension in different modalities. Auditory and written synonym judgement tests (PALPA 49 & 50) were administered and responses analysed for imageability effects.

Nonverbal semantic association was measured using the Pyramids and Palm Trees test (PPT, Howard & Patterson, 1992). In this test participants are required to decide which of two pictures are related to a target picture.

Semantic processing was further investigated using subtests from the Cambridge Semantic Battery (Bozeat et al., 2000) which assesses semantic judgements across modalities with 64 test items. Subtests administered included: the Camel and Cactus test (CCT), a nonverbal test of semantic association from five picture choices; Picture Naming; Verbal Fluency within categories; and a Category Comprehension Test in which participants match a spoken target word to a picture amongst an array of ten items from the same semantic category.

5.6.2.3 Phonological output

Output phonology was assessed using real and nonwords in repetition and read aloud unstandardised tasks (Ruth Herbert, Personal Communication). Control data for these were gathered from control participants. Letter fluency for the letters F, A and S was measured with a subtest from the Cambridge Semantic Memory Battery (Bozeat et al., 2000).

An informal oromotor screen was completed to observe any elements of dysarthria or apraxia affecting participants’ spoken output, including laryngeal, lingual and labial measures of speech production. Participants are asked to cough, move their tongue from side to side, and alternate between lip rounding and spreading. The Dabul Apraxia Battery for Adults (2000) scoring system for oral apraxia was used, which included providing demonstrations if participants did not respond within 10 seconds.

5.6.2.4 Sentence processing

Comprehension of sentences was measured using CAT 9 Comprehension of Spoken Sentences and CAT 10 Comprehension of Written Sentences (Swinburn et al., 2004).

Connected speech samples were gathered using three methods: picture description (CAT 19, Swinburn et al., 2004); Cinderella story recall with pictures; and a conversation sample. The samples were audio recorded with a ZOOM Handy Recorder H2 and transcribed following assessment. Conversation samples of 10 to 15 minute conversations were recorded between the researcher and participants and subsequently the middle five minutes were transcribed and analysed (for the method see Herbert, Best, Hickin, Howard & Osborne, 2012).

5.7 Aphasia profiling

The participants' performance on the language and cognitive tests was analysed to identify the aphasia syndrome of each participant and to investigate specific patterns of language processing across the participants. The method of categorising participants into aphasia syndromes is described by Albyn Davis (1993). Fluency was assessed using the picture description data and Goodglass' (2001) criteria.

5.7.1 PWA background assessment results

Table 5.6 displays individual PWA performance across the cognitive and executive function assessments. Table 5.7 displays individual PWA performance across the language assessments.

Table 5.6: Summary of PWA cognitive tests (raw scores)

	Max	BT	CW	DB	DH	DW	FM	GB	JC	JK	JM	LW	NMH	PG	PS	RP	RT	SE	SH	SL	TS	Normal cut off
Age	-	79	70	46	63	69	75	64	66	64	84	67	70	70	69	60	67	69	52	63	53	-
Aphasia syndrome	-	Co	An	Co	TM	An	TS	Co	TM	An	Br	Br	An	Co	Co	An	Co	An	TM	TM	TS	-
Visuospatial																						
Line bisection^{a}	-	0	0	0	0	3	1	0	0	3	1	0	0	1	1	1	1	2	1	0	1	≥2.5
Symbol cancellation^{b}	12	12	12	11	11	12	8	12	4	12	2	9	11	0	10	12	12	11	11	12	12	18-69: ≤11 70-89: ≤10
Dot counting^{c}	10	10	10	9	8	9	8	10	10	10	9	10	10	8	10	10	10	10	10	10	8	<8
Position discrimination^{c}	20	20	20	20	20	20	19	20	20	20	20	20	19	20	20	19	19	19	20	20	20	<18
Number location^{c}	10	10	10	10	10	10	9	10	10	2	7	10	8	7	10	4	9	10	10	9	10	<7
Cube analysis^{c}	10	9	10	9	10	9	7	9	10	9	8	10	10	7	10	10	9	6	10	6	9	<6
Auditory attention																						
Elevator counting^{d}	7	5	7	7	7	7	6	6	6	7	3	5	7	6	5	5	6	2	7	6	7	6 = doubtful ≤5 = impaired
Elevator counting with distraction^{d} scaled score	10	6	13	6	8	6	5	7	6	4	6	7	7	4	7	7	13	7	4	5	5	≤5 impaired

	Max	BT	CW	DB	DH	DW	FM	GB	JC	JK	JM	LW	NMH	PG	PS	RP	RT	SE	SH	SL	TS	Normal cut off
Age	-	79	70	46	63	69	75	64	66	64	84	67	70	70	69	60	67	69	52	63	53	-
Aphasia syndrome	-	Co	An	Co	TM	An	TS	Co	TM	An	Br	Br	An	Co	Co	An	Co	An	TM	TM	TS	-
Executive function																						
Brixton spatial anticipation[e] no. of errors raw score	54	16	18	33	20	39	26	15	19	20	35	33	16	25	26	14	15	30	14	25	27	5% cut-off 18-45: >25 46-65 > 27 66-80 > 29
Symbol trails[b]	10	7	10	10	3	10	6	10	5	10	6	10	10	2	1	10	10	10	10	5	10	CA 18-69: <9 CA 70-89: <6
Towers of Hanoi (turns to complete 2 discs)	Min = 3 turns	4	3	3	3	6	12	3	5	3	7	3	3	7	4	3	4	5	3	3	5	>6.48 (control mean +2SD)
Raven's matrices	36	32	36	31	35	29	24	34	25	30	17	34	31	18	16	30	34	23	32	25	30	**95th centile** CA 65: 33 CA 70: 31 CA 75: 30 CA 80: 29
Phonological short term memory																						
Digit span	-	2.6	4.7	2.7	3.3	3.5	2.1	2.9	3.1	4.5	1.8	3.7	5.1	2.3	1.5	3.5	4.7	3.5	2.3	3.2	2.5	-
Phoneme span	-	1.8	3.5	2.3	2.6	2.7	1.8	1.4	2.3	2.9	1.5	1.3	2.5	1.9	1.4	2.5	2.3	3.1	1.7	1.7	1.9	-

Note. Underscore denotes scores below the test cut off for normal range. Aphasia syndromes: An = anomic; Co = conduction; TS = transcortical sensory; TM = transcortical motor; Br = Broca's. CA = Chronological age.

[a] CAT Comprehensive Aphasia Test, (Swinburn et al., 2004)

[b] CLQT Cognitive Linguistic Quick Test (Helm-Estabrooks, 2001)

[c] VOSP Visual Object and Space Perception Battery (Warrington & James, 1991)

[d] TEA The Test of Everyday Attention (Robertson et al., 1994)

[e] Burgess & Shallice, 1997.

Table 5.7: PWA speech and language assessments (proportions)

	Max	**BT**	**CW**	**DB**	**DH**	**DW**	**FM**	**GB**	**JC**	**JK**	**JM**	**LW**	**NMH**	**PG**	**PS**	**RP**	**RT**	**SE**	**SH**	**SL**	**TS**	**Control range/ cut off**
Aphasia syndrome	-	Co	An	Co	TM	An	TS	Co	TM	An	Br	Br	An	Co	Co	An	Co	An	TM	TM	TS	-
Auditory input																						
Minimal pairs	40	1.00	.98	1.00	.90	.95	.85	.98	.100	.98	.68	.98	.100	.78	.80	.90	.100	.98	.98	.100	.83	.95-1 .93
Lexical decision	**160**	**.79**	**.92**	**.96**	**.72**	**.83**	**.82**	**.94**	**.78**	**.94**	**.66**	**.96**	**.99**	**.89**	**.74**	**.81**	**.99**	**.84**	**.93**	**.94**	**.94**	**.98**
High Im	40	.88	1.00	.98	.80	.98	.93	1.00	.98	1.00	.98	1.00	1.00	.98	.93	.98	1.00	.98	.95	.98	.98	.996
Low Im	40	.58	.95	.98	.53	.95	.78	.85	.85	1.00	.80	.95	1.00	.88	.68	.85	1.00	.83	.88	.88	.93	.99
Nonwords	80	.85	.86	.95	.78	.69	.79	.95	.76	.88	.43	.83	.98	.85	.68	.70	.99	.79	.95	.96	.93	.95
Nonverbal semantics																						
Picture PPT	52	.100	.98	.94	.96	.92	.96	.98	.90	.96	.79	.96	.92	.98	.73	.96	.90	.96	.96	.90	.88	.94
Picture CCT	64	.89	.89	.94	.78	.89	.78	.97	.73	.86	.69	.95	.67	.97	.50	.92	.77	.72	.86	.69	.86	.8-.97
Semantic processing																						
Auditory synonym judgement	**60**	**.68**	**.97**	**.93**	**.75**	**.87**	**.82**	**.70**	**.75**	**.78**	**.52**	**.92**	**.92**	**.85**	**.75**	**.93**	**.85**	**.82**	**.83**	**.68**	**.80**	-
High imageability	30	.73	1.00	.97	.93	.90	.90	.83	.83	.80	.63	.93	.100	.93	.83	1.00	.93	.97	.87	.73	.93	-
Low imageability	30	.63	.93	.90	.57	.83	.73	.57	.67	.77	.40	.90	.83	.77	.57	.87	.77	.67	.80	.63	.67	-
Written synonym judgement	**60**	**.98**	**.97**	**.90**	**.87**	**.88**	**.92**	**.85**	**.77**	**.88**	**.75**	**.82**	**.90**	**.92**	**.75**	**.93**	**.88**	**.87**	**.88**	**.90**	**.83**	**.87**
High imageability	30	1.00	.97	.93	.90	.97	.93	.87	.87	.93	.80	.97	.93	.97	.87	1.00	.97	.93	.93	.97	.97	-
Low imageability	30	.97	.97	.87	.83	.80	.90	.83	.67	.83	.70	.67	.87	.87	.63	.87	.80	.80	.83	.83	.70	-

	Max	BT	CW	DB	DH	DW	FM	GB	JC	JK	JM	LW	NMH	PG	PS	RP	RT	SE	SH	SL	TS	Control range/ cut off
Aphasia syndrome	-	Co	An	Co	TM	An	TS	Co	TM	An	Br	Br	An	Co	Co	An	Co	An	TM	TM	TS	-
Spoken word to picture matching (CAT)	30	.90	1.00	.97	.90	1.00	1.00	.90	.83	.87	.80	.97	1.00	1.00	.97	.73	.93	.93	.97	.97	.93	.83-1 .83
Written word to picture matching (CAT)	30	.100	.93	.87	.90	.83	.73	.93	.80	.93	.87	.83	.97	.97	.83	.67	.97	1.00	1.00	.87	.90	.90-1. .90
Category comprehension (CSB)	64	.84	.98	.97	.92	.98	.98	.98	.92	.95	.48	.91	.98	1.00	.88	.98	1.00	.91	.94	.97	.97	-
Sentence comprehension (CAT)																						
Spoken sentence comprehension	32	.69	.97	.88	.75	.94	.59	.69	.78	.69	.69	.84	.91	.72	.69	.69	.88	.72	.69	.81	.66	.81-1 .84
Written sentence comprehension	32	.94	.88	.72	.56	.66	.34	.41	.66	.81	.47	.84	.72	.53	.53	.66	.88	.78	.50	.41	.59	.75-1 .72
Spoken word production																						
Picture naming (CSB)	64	.80	.81	.39	.31	.73	.61	.52	.64	.70	.19	.17	.64	.58	.41	.61	.59	.48	.67	.66	.67	-
Output phonology																						
Word repetition	182	.5	.97	.53	.80	.96	.80	.49	.86	.90	.08	.06	.98	.63	.49	.91	.53	.88	.89	.92	.95	.97-1 <97
Word read aloud	182	.92	.98	.56	.83	.73	.76	.63	.68	.90	.05	.04	.91	.85	.44	.99	.96	.86	.89	.76	.68	.98-1 <98
Nonword repetition	26	.15	.81	.8	.62	.88	.15	.12	.54	.65	0	.04	.85	.08	.15	.58	.77	.50	.38	.65	.73	.92-1 <.92
Nonword read aloud	26	.96	.73	.19	.58	.27	0	.12	0	.54	0	0	.65	.04	0	.58	.42	.38	.08	0	.04	.85-1 <.85

Note. Key to aphasia syndromes: An = anomic; Co = conduction; TS = transcortical sensory; TM = transcortical motor; Br = Broca's. All scores represent % correct. Underscore denotes scores below the test cut off for normal range. CAT cut off score and below is that which at least 95% of normal subjects exceed. Written synonym judgement norms taken from Nickels & Cole-Virtue (2004).

5.7.1.1 Cognitive test results

Three participants were within normal limits on all tests of cognition and executive function (CW, NMH and RT). Twelve PWA were within the normal range for performance of tests of visuospatial processing (BT, CW, DB, DH, GB, NMH, PS, RT, SE, SH, SL and TS); JK was the only participant to show deficit on two visuospatial processing tests, with all other PWA showing impairment on one measure (DW, FM, JC, JM, LW, PG, RP). Eight participants performed within normal limits on the measures of auditory attention (CW, DB, DH, DW, GB, JC, NMH, RT) with all other PWA showing deficits on one of the two measures. Seven PWA were within normal limits on all the measures of executive function (BT, CW, GB, JK, NMH, RP, RT). JM and PG demonstrated deficits on three tests of executive function, SH was impaired on Raven's matrices only, whereas the remaining ten participants were impaired only on two measures (Raven's Matrices: all ten; Brixton: DB, DW, LW, SE and TS; Symbol trails: DH, JC, PS, SL; Towers of Hanoi: FM).

5.7.1.2 Speech and language test results

The assessment scores were used to categorise PWA into aphasia syndromes using fluency, lexical comprehension and repetition as the three deciding factors. This process follows the Albyn Davis (1993) decision tree that is based on the Western Aphasia Battery classification system (WAB: Kertesz, 1982). In the first stage of categorisation, connected speech samples were observed for each PWA to analyse fluency. Criteria for fluent versus non-fluent aphasia were applied (Albyn Davis, 1993). Non-fluent production was characterised by language that lacks elaborate syntactic structure, with effortful speech production. Fluent production was characterised by language that is grammatical with typical utterance length, but contains circumlocutions or paraphasias. In addition, speech is produced without excessive effort. In the second stage of categorisation, PWA within the categories of fluent and non-fluent aphasia were characterised based on comprehension ability, and finally in terms of impaired or intact repetition (Albyn Davis, 1993).

CW, DW, JK, NMH, RP, and SE present with profiles of **anomic** aphasia characterised by fluent output, good comprehension and good repetition. Participants' spoken language is characterised by word-finding difficulties and paraphasias.

BT, DB, GB, PG, PS and RT present with profiles of **conduction** aphasia, characterised by fluent output, relatively good comprehension (some mild difficulties) and impaired repetition.

Participants' spoken language output is characterised by word-finding difficulties and paraphasias.

FM and TS present with profiles of **transcortical sensory** aphasia characterised by fluent output, reduced comprehension and impaired repetition. FM shows lower scores on measures of repetition and sentence comprehension than TS.

DH, JC, SH and SL present with profiles of **transcortical motor** aphasia characterised by non-fluent output, functional comprehension (some difficulties) and good repetition. Expressive output is reduced, agrammatic, halting and effortful, with long pauses.

JM and LW present with profiles of **Broca's** aphasia characterised by non-fluent output, mild comprehension difficulties and poor repetition. Expressive output is reduced and appears somewhat telegraphic due to agrammatism, with effortful articulation attempts. JM had very little spoken output.

DH, FM, JM, PS and RP present with auditory discrimination difficulties as demonstrated by low scores on both minimal pairs and auditory lexical decision. In addition, PG and TS showed impaired performance on minimal pairs, whereas BT, DW, JC and SE showed impairment on auditory lexical decision.

When specifically focusing on semantic processing using scores from spoken and written word to picture matching, written synonym judgement, and the two nonverbal measures of picture PPT and CCT, individual PWA can be categorised into five overarching patterns of performance. Firstly, seven PWA present with impairment of written input to semantics and nonverbal semantic measures; four were impaired on both of the nonverbal measures (JC, JM, PS, SL), while three were impaired on one of the nonverbal measures (DW, FM, TS). Based on the measures under consideration, JM was the only PWA to demonstrate impairment in auditory single word access to semantics in addition to orthographic access; none of the PWA demonstrate a deficit in auditory access to semantics independent from orthographic access difficulties. Secondly, RP presents with impaired spoken and written access to lexical semantics via word to picture matching, but intact nonverbal semantic processing. Thirdly, three PWA present with impaired orthographic access to semantics but intact nonverbal semantic processing (DB, GB, LW). A fourth pattern of performance related to four PWA who present with intact lexical semantic processing but impaired nonverbal semantic performance on either one nonverbal measure (CCT: DH, SE) or both nonverbal measures (NMH, RT). Finally, five PWA did not present with semantic impairment on the single word or nonverbal assessments under consideration (BT, CW, JK, PG, SH), however all of these apart from CW demonstrated a deficit at sentence level comprehension.

5.8 Chapter five summary

Chapter 5 has outlined the recruitment and assessment protocol for control participants and PWA, including details of design and procedure of the three experimental semantic tasks included in the study. Results of the PWA background assessment were presented and aphasia syndromes diagnosed. The following three chapters will outline the experimental semantic task results.

Chapter 6 Semantic priming results

6.1 Guide to data analysis

A guide to the upcoming task analysis is outlined below. Chapters 6, 7 and 8 present the experimental SP, WPV and WPM tasks, respectively. In Chapter 9 comparisons across experimental tasks are completed. In section 9.3, individual PWA performance on the experimental semantic tasks is compared to the control group, and two subgroups of PWA performance are identified. Chapter 10 consists of investigation of the relationship between PWA semantic task performance in relation to semantic and cognitive assessment data; consideration is also given to subgroup performance on these measures.

Throughout, Kolmogorov-Smirnov tests were conducted to assess the normality of the distribution for accuracy and response latency data for all three tasks and both groups of participants. Where non-normal distribution was found, non-parametric statistical tests were used. Non-parametric tests were deemed to be more conservative given the relatively small sample sizes with the PWA group. Full results of the Kolmogorov-Smirnov test for each participant group and task, including skewness and kurtosis, are presented in Appendix N. Unless otherwise stated, effect sizes for significant results are categorised using Cohen's (1988) criteria of small (r =.10 to .29), medium (r =.30 to .49) and large (r =.50 to 1.0) effect sizes. Where partial eta squared is reported, criteria of small (.01) medium (.06) and large (.14) effect sizes are applied (Cohen, 1988).

6.2 Guide to semantic priming analysis

In this chapter, the results of the SP task for control participants and PWA are described. Results are divided into six main sections:

i. Accuracy and errors rates for both groups of participants;
ii. Preparation of raw data for response latency analysis;
iii. Statistical analyses for control participant data, including by-participant and by-item analyses of semantic priming effect and the effect of prime type on response latency;
iv. Statistical analyses for PWA time one data, including by-participant and by-item analyses of semantic priming effect and the effect of prime type on response latency;
v. Between-group comparisons of the priming effect;
vi. Individual PWA analyses, including the effects of priming, prime-type and time of testing (first or second semantic priming exposure).

For control participants and PWA, the priming effects presented are the main effect of relatedness i.e. the difference between the related and unrelated conditions, and the effect of relationship type, i.e. the difference between semantically similar and associated prime conditions. Exact significance (2-tailed) is reported throughout for all results.

6.2.1 Accuracy and error rates for control participants and PWA

Error and accuracy rates for all stimuli categories (targets, primes, fillers and nonwords), and with categories collapsed into words and nonwords are presented (see Table 6.1 for control participants and Table 6.2 for PWA). Note that PWA completed both lists in the semantic priming task and controls saw only one list, therefore the PWA total number seen in each category is double that of the control group, e.g. for targets (*n* = 100) whereas each control completed only half of this (*n* = 50). Figure 6.1 illustrates individual control participant and PWA accuracy to targets in the Semantic Priming task (i.e. lexical decision accuracy).

One control participant was excluded from the results because they made a high proportion of errors. They made an overall error response of 17.2% in comparison to the group mean of 2%, and made 11.6% of errors for nonword decisions, the group mean for which was 2%. This participant was withdrawn from all control analysis of the semantic experimental tasks to enable direct comparison between the same group of participants across tasks.

Table 6.1: Semantic priming task error rates and accuracy values for control participants

	Control participant accuracy				**Control participant errors**			
	Mean	Mean proportion	Range	Range proportion	Mean	Mean proportion	Range	Range proportion
Targets (*n*=50)	49.48	.99	47-50	.94-1	0.53	.003	0-3	0-.02
Primes (*n*=50)	48.43	.97	43-50	.86-1	1.58	.03	0-7	0-.14
Fillers (*n*=25)	24.35	.97	22-25	.88-1	0.65	.03	0-3	0-.12
Total real words (*n*=125)	122.25	.98	113-125	.90-1	2.75	.02	0-12	0-.10
Nonwords (*n*=125)	122.18	.98	110-125	.88-1	2.83	.02	0-15	0-.12
Total overall (*n*=250)	**244.43**	**.98**	**226-250**	**.90-1**	**5.58**	**.02**	**0-24**	**0-.10**

Table 6.2: Semantic priming task error rates and accuracy values for PWA

	PWA accuracy				**PWA errors**			
	Mean	Mean proportion	Range	Range proportion	Mean	Mean proportion	Range	Range proportion
Targets (*n*=100)	95.65	.96	84-100	.84-1	4.35	.04	0-16	0-.16
Primes (*n*=100)	94.35	.94	87-100	.87-1	5.65	.06	0-13	0-.13
Fillers (*n*=50)	46.40	.93	40-50	.80-1	3.60	.07	0-10	0-.20
Total real words (*n*=250)	236.40	.95	217-250	.87-1	13.60	.05	0-33	0-.13
Nonwords (*n*=250)	228.10	.91	181-249	.72-1	21.90	.09	1-69	0-.28
Total (*n*=500)	**464.50**	**.93**	**419-491**	**.84-.98**	**35.50**	**.18**	**9-81**	**.07-.37**

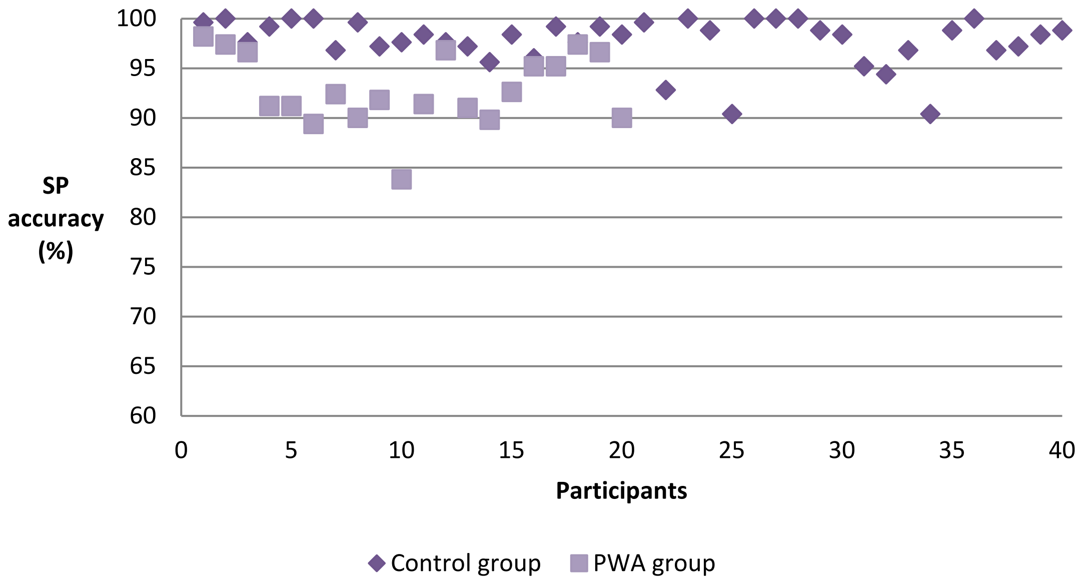

Figure 6.1: Individual participant SP task accuracy

The control group (*Md* proportion = 98.35, *n* = 40) was significantly more accurate in overall lexical decision than the PWA group (*Md* proportion = 92.10, *n* = 20), *U* = 89.5, *z* = -4.88, *p* <.001. Both groups showed the highest accuracy with target stimuli. The control group made most of their errors on prime and filler words (i.e. real words) whereas the PWA group produced most of their errors on nonwords.

6.2.2 Error analysis

Separate within-group comparisons of error rate across stimulus types were made for the control group and PWA group, using Kruskal-Wallis tests. Significant differences in errors as a function of stimulus types were found within both groups (see Table 6.3). Therefore, post-hoc tests were completed using Mann-Whitney U tests. For the post-hoc comparisons, Bonferroni correction was applied (=.05/7), resulting in an adjusted value of alpha, and significance rates of .007 being applied. Data are reported in Table 6.3 and Table 6.4.

Table 6.3: Median error rates and error analysis

	Target	**Primes**	**Fillers**	**Non-words**	**Real words**	**χ^2**	***df***	***p***
Control group	.00	2.00	.00	1.60	1.60	19.85	3	<.001***
	(.58)	(3.51)	(3.80)	(2.89)	(2.37)			
PWA group	2.5	5.5	7.00	7.80	3.80	8.36	3	.036*
	(4.46)	(3.62)	(5.29)	(6.27)	(3.56)			

Note. Standard deviation in brackets. χ^2 = Kruskal-Wallis Test Chi-Square value; *df* = degrees of freedom; *p* = significance level.
****p* ≤ .001. **p* ≤ .05.

Table 6.4: Within-group pairwise comparisons of stimuli error rate

	Control group			**PWA group**		
Stimulus types	*U*	*z*	*p*	*U*	*z*	*p*
Targets vs. primes	422.00	-3.99	<.001***	145.5	-1.48	.141
Targets vs. fillers	624.00	-1.99	.046	134.0	-1.80	.071
Targets vs. nonwords	372.00	-4.37	<.001***	103.5	-2.62	.009
Primes vs. fillers	682.50	-1.22	.234	167.5	-.88	.387
Primes vs. nonwords	710.50	-.88	.382	136.0	-1.73	.084
Fillers vs. nonwords	697.00	-1.03	.304	169.5	-.827	.402
Real words vs. nonwords	782.00	-.18	.863	129.0	-1.92	.053

Note. U and *z* = Mann-Whitney U Test statistics, *p* = significance.
***p ≤ .001.

The control group were more accurate in the target category; this reached significance for the comparisons with primes and nonwords. As was the case for controls, the PWA group responded more accurately to targets than to other sets. This did not reach significance in any category, although the difference in accuracy rates between targets and nonwords was approaching the adjusted significance level, with more errors made in the nonword category.

6.3 Response latencies: data preparation

Responses were coded as correct if a correct lexical decision was made within a delineated time frame after stimulus presentation. For control participants, any responses under 200ms were classified as errors and removed from analyses. Due to the experimental design, control participants could not respond after 2000ms, therefore instances when a response was not provided in the 2000ms timeframe were automatically classified as errors. PWA had unlimited time within which to respond, and a longer threshold of 200ms to 10000ms was applied for PWA when trimming the data. Responses to stimuli were classified as errors and excluded from analyses if response latencies fell outside of these thresholds, or if the participant made an overt error. A minimum threshold of 200ms was applied as it is thought that the timeframe of access to lexical concepts is within 150-200ms from picture presentation (Indefrey & Levelt, 2004), therefore by 200ms participants should have accessed the semantics of a written word and any response latencies below 200ms are unlikely to be influenced by semantic processing (Levelt, Praamstra, Meyer, Helenius, & Salmelin, 1998). Within semantic priming studies, a variety of response cut-offs are applied to reduce the influence of data which may reflect strategic processing. PWA demonstrate generally slower response times and processing on semantic priming tasks in comparison to control participants, therefore the unlimited response window enabled accurate response data to be captured, while still providing a limit for maximum response time for responses to be included as accurate when trimming the data.

Each participant's data were then viewed and descriptive statistics generated. In the by-participant analyses, lexical decision latencies which deviated more than two standard deviations from an individual participant's mean were replaced with the mean plus or minus two standard deviations as appropriate. This process was applied separately across the different stimuli categories including primed targets, unprimed targets, primes, fillers and nonwords. This method of trimming is recommended for use in reaction time data to reduce the effect of outliers on the overall mean (Ratcliff, 1993; Field, 2013). Data were then viewed at the item level and descriptive statistics generated. Each item's mean and standard deviation were computed and where an item's lexical decision latencies deviated more than two standard deviations from their mean, the value was replaced with the mean plus or minus two standard deviations as appropriate.

6.4 Planned group analyses for control participants

For the control participant data, two analyses of variance (ANOVA) were completed. For the by-participant analysis a 2x2 repeated measures ANOVA was conducted. The first factor was within-subject with two levels: related and unrelated prime-target pairs. The impact of the relatedness condition was investigated by comparing response latency to targets in one condition, where the preceding word was related to the target, to response latency in the second condition, where the preceding word was unrelated. The second factor of stimuli relationship was a within-subjects factor with two levels: the related word preceding the target was either: 1) a semantically similar word to the target (e.g. *cat-dog*); or 2) an associated word (e.g. *cow-grass*), and the impact of this on participant response latency was explored.

For the by-item analysis, a 2x2 mixed ANOVA was conducted to investigate the impact of the relatedness condition and stimuli relationship on response latency for target items. The first factor of relatedness was within-subject with two levels: related and unrelated prime-target pairs. For the by-item level, the second factor of stimuli relationship was between-subject, as different targets were present in each condition.

6.4.1 By-participant analysis of reaction times – control group results

Table 6.5 displays the by-participant control group mean reaction times to semantically similar and associated targets, when presented in related or unrelated conditions.

Table 6.5: Control participant by-participant mean reaction times (ms) to targets in the related and unrelated conditions

	All targets	Semantically similar targets	Associated targets
Related condition	929 (114)	930 (123)	927 (110)
Unrelated condition	945 (110)	948 (117)	939 (110)
Priming effect	**16**	**18**	**12**

Note. Standard deviation in brackets.

A main effect of priming with a medium effect size was found, (*F* (1, 39) = 4.69, *p* = .036, partial eta squared = .107), with participants producing significantly faster reaction times to targets in the related condition than in the unrelated condition, indicating a semantic priming effect overall. There was no main effect of type of stimuli relationship, (*F* (1, 39) = .994, *p* = .325, partial eta squared = .025), indicating no significant difference between reaction times to semantically similar and associated targets. There was no interaction between priming condition and stimuli relationship (*F* (1, 39) = .145, *p* = .706, partial eta squared = .004), indicating that the priming effect for the semantically similar stimuli and associated stimuli was of the same magnitude.

6.4.2 By-item analysis of reaction times – control group results

Table 6.6 shows the by-item control group mean reaction times to semantically similar and associated targets, when presented in related or unrelated conditions.

Table 6.6: Control participant by-item mean reaction times (ms) to targets in related and unrelated conditions

	All targets	Semantically similar targets	Associated targets
Related condition	933 (62)	933 (55)	935 (75)
Unrelated condition	947 (63)	952 (63)	938 (64)
Priming effect	**14**	**19**	**3**

Note. Standard deviation in brackets.

Participants responded more rapidly to targets in the related condition than in the unrelated condition. However, there was no main effect of relatedness, indicating that there was no significant priming effect, *F* (1, 48) = .793, *p* = .378, partial eta squared = .016. There was no main effect of stimuli relationship, *F* (1, 48) = .187, *p* = .668, partial eta squared = .004, indicating that participants responded as rapidly to words which were preceded by a semantically similar word as they did to those preceded by an associated word. There was no significant interaction between priming and stimuli relationship, *F* (1, 48) = .428, *p* = .516, partial eta squared = .009.

6.4.3 Summary of control group performance

A significant by-participant semantic priming effect with medium effect size was demonstrated, which was of the same magnitude for words preceded by a semantically similar word as for those preceded by an associated word. In the by-item analysis, there was a trend towards a priming effect but this was not significant. As in the by-participant analysis, there was no difference between the two types of semantic relationship, and no significant interaction between the two factors. The main effect found at the participant level, therefore, did not generalise to the item level, although did approach significance.

6.5 Planned group analyses for people with aphasia

In the PWA group analysis, only data from testing time one was used. At time one, participants had only been exposed to each target once, in either the related or the unrelated condition. This removed the possible contamination of the data by repetition priming or practice effects due to PWA being exposed to each target twice, once in each condition. Although the PWA reaction data group were normally distributed at the by-item level, at the by-participant level the data were non-normally distributed for the related condition. The PWA sample was small and it was not appropriate to transform the values, therefore non-parametric tests were used.

As for the control group, effects of relatedness condition and stimuli relationship were investigated. For the by-participant analysis, repeated measures Wilcoxon-Signed Rank Tests were conducted to compare i) response latency to targets in the related versus unrelated prime condition and ii) semantically similar versus associated primes. The same analysis was completed at the by-item level for effect of relatedness condition. However, for the effect of stimuli relatedness, a Mann-Whitney U Test was used to investigate the effect of stimuli relationship, as different items were used in each condition.

6.5.1 By-participant analysis of reaction times – PWA group results

Table 6.7 displays the by-participant PWA group median response latencies to semantically similar and associated targets, when preceded either by a related prime or an unrelated prime.

Table 6.7: PWA by-participant mean reaction times (ms) to targets in related and unrelated conditions

	All targets	Semantically similar targets	Associated targets
Related condition	1272 (301)	1270 (289)	1278 (333)
Unrelated condition	1329 (321)	1337 (316)	1313 (334)
Priming effect	**57**	**67**	**35**

Note. Standard deviation in brackets.

The PWA group demonstrated a significant effect of relatedness, z = -3.85, p < .001, with a large effect size (r = .61), with shorter response latencies in the primed condition (*Md* = 1244ms) than in the unprimed condition (*Md* = 1294). Although there was a trend for a greater priming effect for semantically similar (*Md* = 48) than associated primes (*Md* = -1.50), this did not reach significance.

6.5.2 By-item analysis of reaction times – PWA group results

Table 6.8 shows the by-item PWA group median response latencies to semantically similar and associated targets when presented in related or unrelated conditions.

Table 6.8: PWA by-item mean reaction times (ms) to targets in related and unrelated conditions

	All targets	Semantically similar targets	Associated targets
Related condition	1127 (236)	1311 (152)	1336 (228)
Unrelated condition	1155 (241)	1368 (171)	1354 (136)
Priming effect	**28**	**57**	**18**

Note. Standard deviation in brackets.

At the by-item level, there was a trend towards quicker responses in the related condition (*Md* = 1057) than in the unrelated condition (*Md* = 1088), however this did not reach significance (z = -1.66, p < .098). There was a trend for a greater priming effect for semantically similar primes (*Md* = 34.5) than for associated primes (*Md* =78.5), but this did not reach significance (U = 258, z = -.61, p = .555).

6.5.3 Summary of PWA group performance

The PWA group of participants demonstrated a semantic priming effect at the by-participant level, and a trend of semantic priming at the by-item level which did not reach significance. There was no significant difference in the priming effect between the semantically similar and associated conditions at either level of analysis.

6.6 Between-group comparison: planned analyses

For the group analysis of the PWA data, the response latencies from the control group data were compared to the PWA group results, at both the by-participant and by-item levels, using data from time one only. This allowed data comparisons to be made where all participants had only been exposed to each target once, as explained in section 6.5.

For both sets of analyses a 2x2 mixed ANOVA was conducted with a within-subject factor of relatedness with two levels; related and unrelated. The second factor was a between-subject variable of group with two levels; control participant or PWA group. There was no significant interaction found between relatedness and stimuli relationship in the previous control and PWA by-participant and by-item control participant analyses, therefore the factor of stimuli relationship was excluded. Parametric tests were used in the between-group comparison as there is no non-parametric alternative to a mixed ANOVA, and the interaction between relatedness and group was of particular interest.

6.6.1 Comparison of control and PWA group response latencies: by-participant

The spread of the SP mean reaction time data for individual participants can be viewed in Figure 6.2 for overall response latency (i.e. time to lexical decision) and Figure 6.3 for the difference in response latency to targets in the related and unrelated conditions (i.e. potential semantic priming effect) .

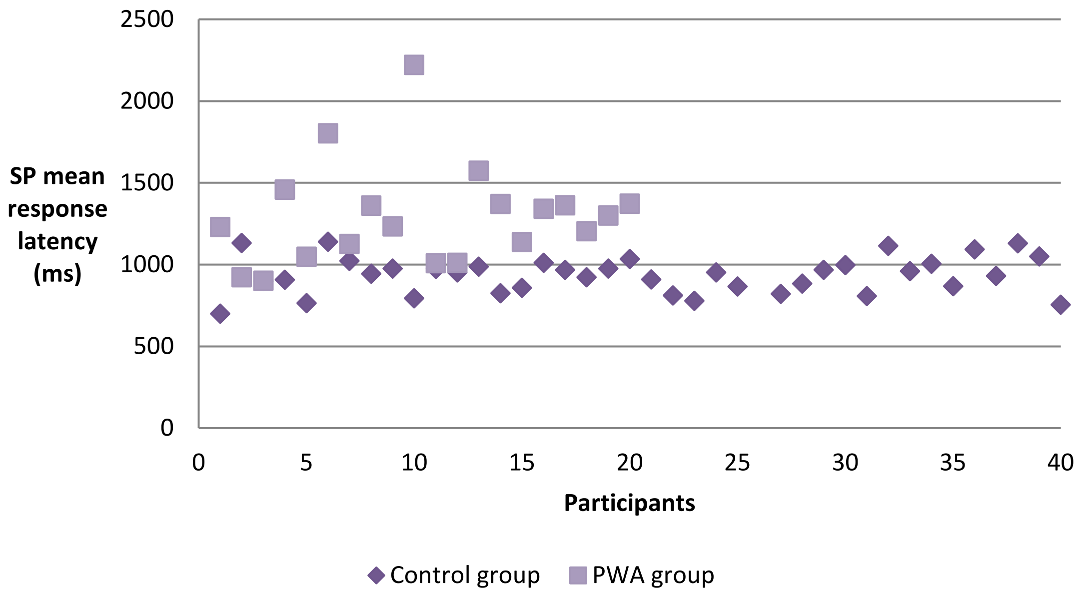

Figure 6.2: Individual participant Semantic Priming task response latency

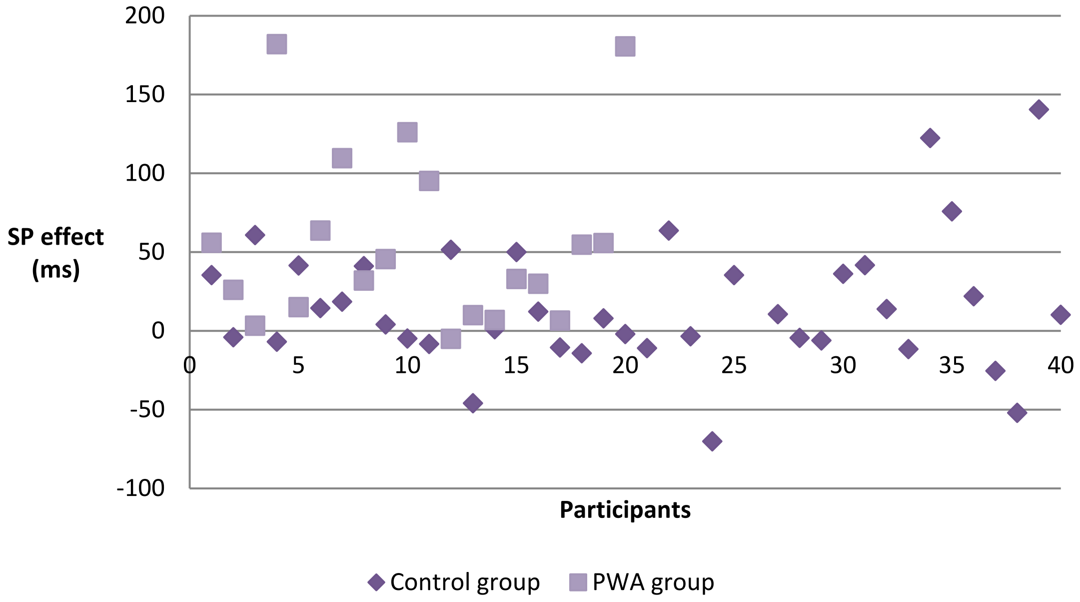

Figure 6.3: Individual participant Semantic Priming effect

Control participant and PWA group response latencies to targets in related and unrelated conditions at the participant level are presented in Table 6.9 and Figure 6.4.

Table 6.9: Group response latency (ms) to targets in the semantic priming task: by-participant level

	Control participants	**Participants with aphasia**
Related condition	928 (114)	1326 (384)
Unrelated condition	945 (110)	1365 (402)
Priming effect	**17**	**39**

Note. Standard deviation in brackets.

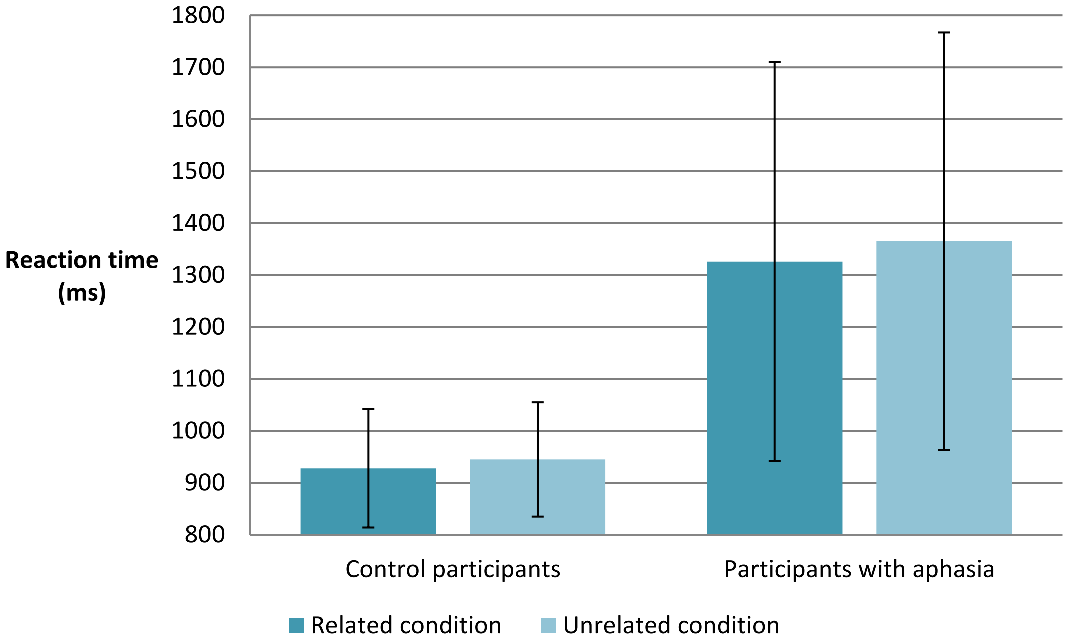

Figure 6.4: Group response latency to targets in related and unrelated prime conditions: by-participant

There was no significant interaction between relatedness condition and group *F* (1, 58) = 1.99, *p* = .164, partial eta squared = .033. Both groups responded faster to targets in the related condition compared to the unrelated condition. There was a main effect of relatedness condition with a large effect size, demonstrating a significant priming effect, *F* (1, 58) = 11.42, *p* = .001, partial eta squared = .164. There was a significant main effect of group and a large effect size, with the control group responding significantly faster than people with aphasia, *F* (1, 58) = 38.37, *p* < .001, partial eta squared = .398.

6.6.2 Comparison of control and PWA group response latencies: by-item

Control and PWA group response latencies to targets in related and unrelated conditions at the item level are presented in Table 6.10 and Figure 6.5.

Table 6.10: Group response latency (ms) to targets in the semantic priming task: by-item level

	Control participants	**Participants with aphasia**
Related condition	933 (62)	1320 (181)
Unrelated condition	947 (63)	1363 (158)
Priming effect	**14**	**43**

Note. Standard deviation in brackets.

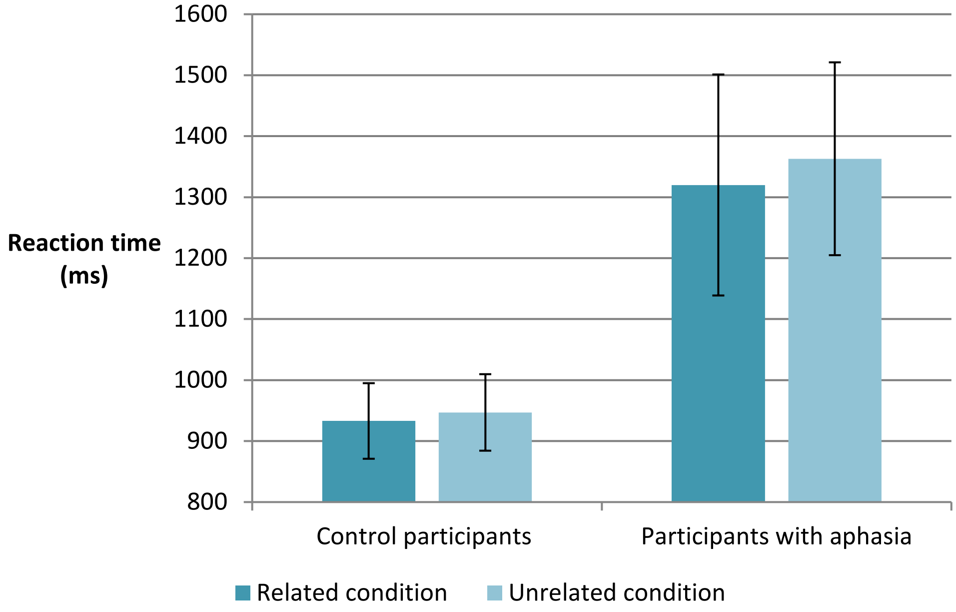

Figure 6.5: Group response latency to targets in related and unrelated prime conditions: by-item

There was no significant interaction between relatedness condition and group *F* (1, 98) = 3.813, *p* = .317, partial eta squared = .010. Both groups responded faster to targets in the related condition compared to those in the unrelated condition. There was no main effect of relatedness condition, indicating that there was no significant priming effect, however this was approaching significance, *F* (1, 98) = 3.813, *p* = .054, partial eta squared = .037. There was a significant main effect of group and a large effect size, with control participants responding significantly faster than people with aphasia, *F* (1, 98) = 359.06, *p* < .001, partial eta squared = .786.

6.6.3 Summary of semantic priming group comparison

Comparison of the control data and PWA data from time one of testing demonstrated that there was no interaction between the factors of relatedness and group at either level of analysis. Control participants demonstrated faster response latencies compared to the PWA group, at both the participant and item level of analysis. Both groups responded faster to the targets in the related condition than the unrelated condition, this reached a significant priming effect at the participant level and was approaching significance at the item level, indicating an overall positive effect of relatedness on response latency.

6.7 Individual PWA analysis of semantic priming

Analysis of the effects of relatedness and stimuli relationship on each individual PWA's lexical decision latencies was conducted using time one and time two data. Therefore response latencies for all the targets that were accurately responded to, in both the related and unrelated conditions, were scrutinised for each individual.

The number of errors made by each participant determined the total number of targets included in the analyses. When an error was made to a target, in either the related or the unrelated condition, the reaction times were removed for the error response and for the same target in the alternate condition, even if the response in the alternate condition was accurate. Thus each participant's dataset consisted of the total number of items correct in both conditions, and a different number of items were potentially entered into analysis for each PWA. Full descriptive statistics can be viewed in Table 6.11 - this includes overall priming effect as well as the priming effect for semantically similar and associated target pairs.

Table 6.11: Descriptive statistics: PWA overall, semantically similar and associated mean priming effect (ms)

	1	2	3	4	**5**	6	7	8	**9**	10	11	12
PWA	Total targets in each condition	Related condition	Unrelated condition	**Difference overall (unrelated - related)**	Total semantically similar targets (*n*=32)	Semantically similar related condition	Semantically similar unrelated condition	**Semantically similar difference (unrelated - related)**	Total associated targets (*n*=18)	Associated related condition	Associated unrelated condition	**Associated difference (unrelated - related)**
BT	50	1202 (269)	1258 (331)	**56**	32	1181 (300)	1272 (328)	**91**	18	1240 (205)	1235 (343)	**-5**
CW	49	912 (184)	938 (159)	**26**	31	892 (147)	939 (170)	**47**	18	946 (236)	936 (159)	**-10**
DB	48	901 (209)	904 (176)	**3**	31	894 (206)	926 (191)	**32**	17	914 (222)	864 (143)	**-50**
DH	40	1368 (426)	1550 (539)	**182**	24	1454 (503)	1539 (572)	**85**	16	1240 (232)	1567 (504)	**327**
DW	41	1041 (217)	1056 (201)	**15**	27	1026 (182)	1075 (206)	**49**	14	1068 (279)	1018 (192)	**-50**
FM	35	1773 (402)	1836 (585)	**63**	23	1730 (307)	1844 (680)	**114**	12	1855 (548)	1821 (365)	**-34**
GB	41	1072 (167)	1182 (273)	**110**	25	1097 (182)	1227 (307)	**130**	16	1033 (138)	1111 (199)	**78**
JC	43	1346 (197)	1378 (158)	**32**	27	1354 (232)	1399 (176)	**45**	16	1333 (123)	1343 (120)	**10**
JK	49	1213 (164)	1258 (298)	**45**	32	1211 (150)	1223 (153)	**12**	17	1216 (194)	1325 (462)	**109**

	1	2	3	4	**5**	6	7	8	**9**	10	11	12
PWA	Total targets in each condition	Related condition	Unrelated condition	**Difference overall (unrelated - related)**	Total semantically similar targets (*n*=32)	Semantically similar related condition	Semantically similar unrelated condition	**Semantically similar difference (unrelated - related)**	Total associated targets (*n*=18)	Associated related condition	Associated unrelated condition	**Associated difference (unrelated - related)**
JM	47	2159 (962)	2285 (821)	**126**	31	2071 (630)	2261 (894)	**190**	16	2328 (1413)	2332 (683)	**4**
LW	50	961 (147)	1057 (223)	**96**	32	959 (170)	1069 (235)	**110**	18	966 (99)	1035 (203)	**69**
NMH	49	1014 (121)	1009 (112)	**-5**	32	990 (100)	1014 (127)	**24**	17	1059 (147)	1000 (79)	**-59**
PG	47	1570 (439)	1580 (566)	**10**	31	1582 (472)	1614 (609)	**32**	16	1547 (383)	1515 (482)	**-32**
PS	43	1368 (305)	1375 (261)	**7**	28	1326 (266)	1408 (302)	**82**	15	1447 (363)	1313 (149)	**-134**
RP	49	1122 (326)	1155 (338)	**33**	32	1144 (370)	1168 (361)	**24**	17	1082 (225)	1132 (299)	**50**
RT	46	1327 (206)	1357 (313)	**30**	30	1307 (198)	1382 (358)	**75**	16	1363 (220)	1310 (210)	**-53**
SE	49	1360 (295)	1366 (292)	**6**	31	1371 (316)	1403 (297)	**32**	18	1341 (264)	1304 (282)	**-37**
SH	49	1179 (166)	1234 (215)	**55**	32	1198 (177)	1221 (209)	**23**	17	1144 (139)	1257 (232)	**113**
SL	48	1274 (183)	1329 (244)	**55**	31	1292 (186)	1312 (229)	**20**	17	1240 (177)	1361 (272)	**121**
TS	47	1284 (415)	1464 (515)	**180**	30	1329 (453)	1452 (541)	**123**	17	1204 (335)	1485 (482)	**281**

Note. Standard deviation in brackets.

Considering the overall effect of relatedness (Table 6.11, column 4), all PWA demonstrated faster response latencies in the related condition, with the exception of NMH. Four participants (DH GB, JM, TS) demonstrated a large difference in response latency dependent on relatedness condition, with a large facilitation in the related condition that can be classified as hyperpriming. All twenty PWA demonstrated faster response latencies for semantically similar targets in the related condition (column 8). Data from the associated condition were more mixed. Ten PWA demonstrated faster response latencies to targets in the related condition, whereas ten participants demonstrated slower response latencies (i.e. inhibition) in this condition compared with the unrelated condition (column 12). Therefore, like the control group, ten PWA showed a pattern of priming for both semantically similar and associated items, with six PWA showing a larger associated than semantically similar priming effect.

6.7.1 Planned analyses

With the exception of JC, all of the individual PWA generated non-normally distributed response latency data (see Tables N1 and N2 in Appendix N for full breakdown of Kolmogorov-Smirnov test of normality results). Therefore, non-parametric analyses were run for all individual PWA data analysis.[14] Response latencies to targets were entered into two stages of analysis to investigate:

i) the effect of relatedness (whether a target is preceded by a related or unrelated prime), using Wilcoxon Signed Rank Tests;
ii) the effect of stimuli type (semantically similar or associated) on priming effect, using Mann-Whitney U Tests.

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[14] Parametric tests were also conducted and resulted in the same findings as the non-parametric analysis, except for a medium effect size for the participants presenting with a semantic priming effect. Two PWA (SL and SH) also demonstrated a borderline main effect of relatedness approaching significance. Please see Table O1 in Appendix O for details.

6.7.2 Individual PWA semantic priming results

The first stage of individual PWA analysis of effect of relatedness is presented in Table 6.12, with Figure 6.6 illustrating each individual's overall priming effect.

Table 6.12: Individual PWA effect of prime-target relatedness

PWA	Median response latency to related prime-target pairs (ms)	Median response latency to unrelated prime-target pairs (ms)	*n*	*z*	*p*	*r*
BT	1160	1044	100	-.907	.369	-
CW	860	862	98	-.841	.405	-
DB	835	877	96	-.164	.873	-
DH	1266	1428	80	-2.156	.030*	.24
DW	994	992	82	-.233	.410	-
FM	1728	1680	70	-.342	.739	-
GB	1045	1109	82	-2.441	.014*	.27
JC	1310	1360	86	-.851	.400	-
JK	1178	1228	98	-1.005	.319	-
JM	1866	2046	94	-1.169	.246	-
LW	926	993	100	-2.81	.004**	.28
NMH	993	994	98	-.116	.910	-
PG	1547	1430	94	-.603	.552	-
PS	1293	1297	86	-.006	.998	-
RP	1060	1107	98	-.836	.408	-
RT	1311	1336	92	-.361	.723	-
SE	1310	1313	98	-.226	.825	-
SH	1178	1180	98	-1.296	.198	-
SL	1240	1271	96	-1.432	.154	-
TS	1113	1245	94	-2.223	.025*	.23

Note. n = number of targets entered into analysis; z = Wilcoxon Signed Rank Test; *p* = significance level; *r* = effect size.
***p* ≤ .01. **p* ≤ .05.

Nineteen PWA showed a tendency to respond faster to targets in the related condition than in the unrelated condition, and this was significant for four of the participants (DH, GB, LW, TS). All four showed small effect sizes (Cohen, 1988).

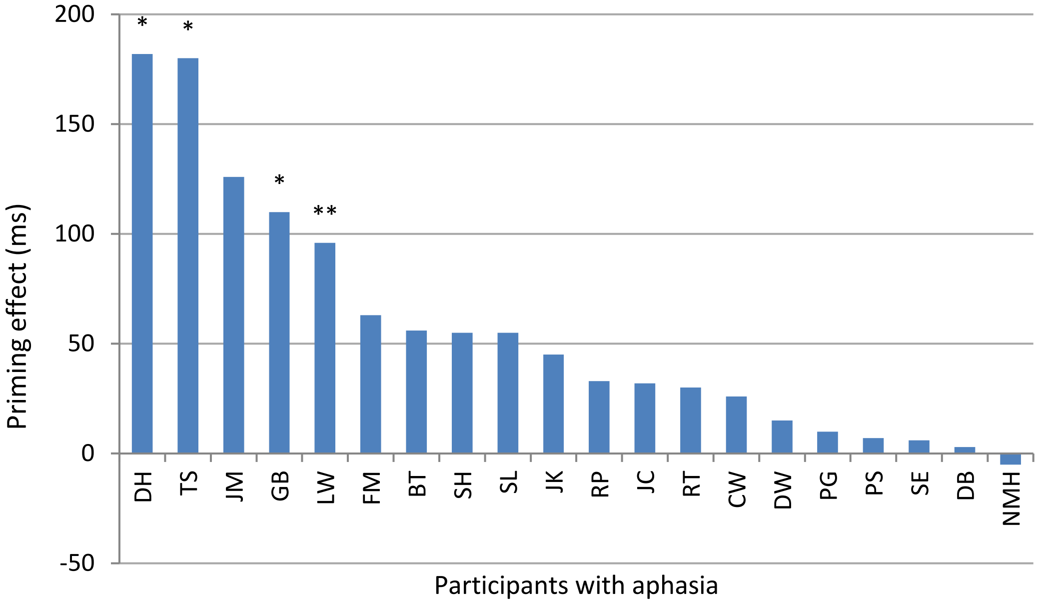

Figure 6.6: Individual PWA priming effect
**$p \leq .01$; *$p \leq .05$.

The second stage of the individual PWA analysis compared the relatedness effect in semantically similar and associated prime conditions. Mean individual priming effects for each stimuli relationship are illustrated in Figure 6.7 for the semantically similar prime condition and Figure 6.8 for the associated prime condition.

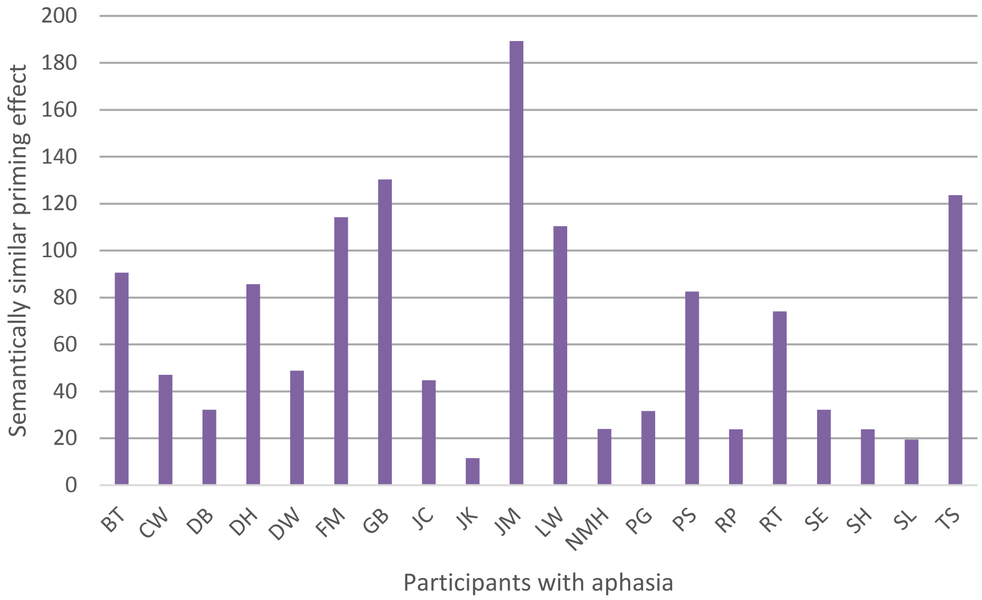

Figure 6.7: Individual PWA semantically similar priming effect - difference between related and unrelated means

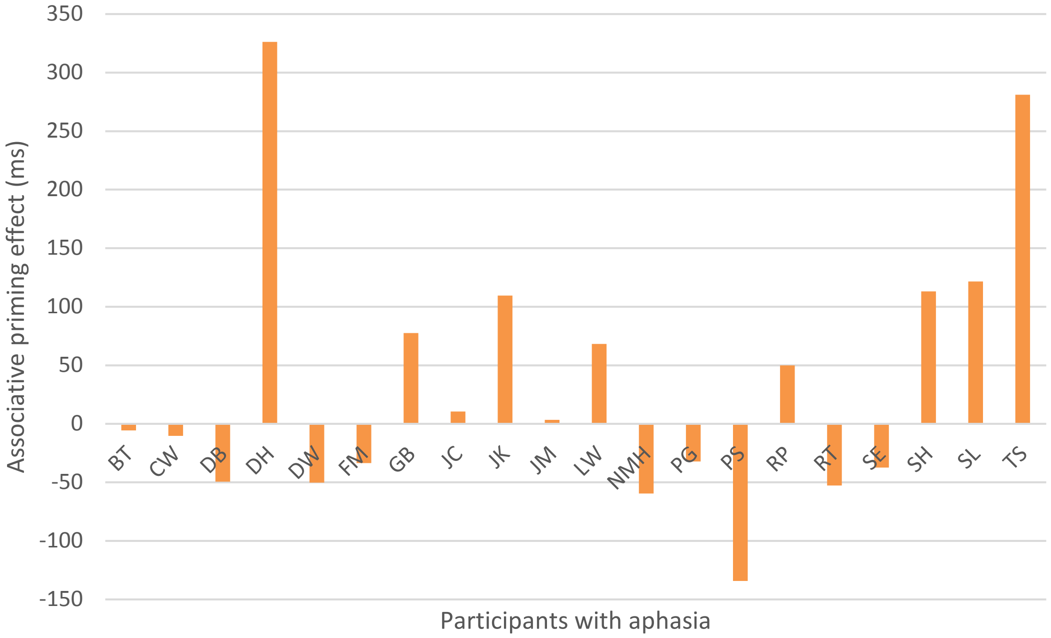

Figure 6.8: Individual PWA associative priming effect - difference between related and unrelated means

Table 6.13 displays the comparison of the two prime conditions, in which the difference between the related and unrelated reaction times in semantically similar and associated prime conditions are compared in terms of mean difference, and also the results of the non-parametric analyses presented with median figures. In the highlighted column presenting mean priming difference between stimuli relationship type, positive values indicate greater priming in the semantically similar condition, whereas negative values indicate greater priming in the associated condition.

Table 6.13: Effect of stimuli relationship type on priming effect

PWA	Mean semantically similar relatedness effect (ms)	Mean associated relatedness effect (ms)	Difference between semantically similar and associated effect (ms)	Median semantically similar effect of relatedness (ms)	Median associated effect of relatedness (ms)	*n*	*U*	*z*	*p*
BT	91	-5	**96**	66	-56	50	218	-1.43	.157
CW	47	-10	**57**	2	0	49	248	-0.65	.521
DB	32	-50	**82**	51	-116	48	208	-1.20	.236
DH	85	327	**-242**	95	250	40	141	-1.42	.159
DW	49	-50	**99**	65	2	41	161	-0.78	.442
FM	114	-34	**148**	-83	278	35	126	-0.42	.694
GB	130	78	**52**	67	59	41	172	-0.76	.454
JC	45	10	**35**	65	32	43	194	-0.57	.580
JK	12	109	**-97**	51	65	49	257	-0.32	.759
JM	190	4	**186**	-66	597	47	220	-0.63	.538
LW	110	69	**41**	69	24	50	231	-1.16	.250
NMH	24	-59	**83**	42	-50	49	200	-1.52	.130
PG	32	-32	**64**	-117	-127	47	247	-0.02	.987
PS	82	-134	**216**	25	-51	43	150	-1.54	.126
RP	24	50	**-26**	48	-67	49	269	-0.06	.954
RT	75	-53	**128**	34	-34	46	192	-1.12	.269
SE	32	-37	**69**	-1	-34	49	266	-0.28	.786
SH	23	113	**-90**	-0.5	115	49	213	-1.24	.220
SL	20	121	**-101**	1	66	48	204	-1.29	.200
TS	123	281	**-158**	26	235	47	187	-1.51	.135

Note. n = number of targets entered into analysis; *U* and *z* = Mann-Whitney U Test statistics; *p* = significance level.

All PWA recognised the targets faster in the related semantically similar conditions than in the corresponding unrelated condition, whereas in the associated condition 10 PWA were slower to recognise targets in the related condition than in the corresponding unrelated condition (BT, CW, DB, DW, FM, NMH, PG, PS, RT, SE). For fourteen PWA the difference between related and unrelated conditions was greater for the semantically similar then for the associated targets, and for six PWA the difference between related and unrelated conditions was greater for associated than for semantically similar targets (DH, JK, RP, SH, SL & TS). However, no PWA demonstrated a significant effect of stimuli relationship type i.e. no significant difference in the magnitude of the priming effect for targets preceded by semantically similar or associated primes.

In summary, for the individual PWA analysis conducted thus far, 19 showed smaller response latencies in the related condition, of which four were significant. Fourteen PWA showed larger effects of relatedness in the semantically similar condition than in the associated condition, with six showing larger effects in the associated condition, of which none were significant. Therefore, it can be concluded that for the four PWA who demonstrated a main effect of relatedness, this was of the same magnitude for prime-target relationships that were semantically similar and associated.

6.7.3 Patterns of performance in PWA

Subsequent analyses were completed for all PWA. The purposes of these were twofold; firstly the effect of repeated exposure to targets was investigated. Typically in semantic priming studies, participant results are analysed at a group level and therefore participants are only exposed to each target once, as in the group analysis. In the current semantic priming task, PWA saw each target on two occasions, in both the related and unrelated conditions, to allow individuals to act as their own controls. The analysis was completed to investigate whether repetition priming or practice effects were present for the PWA with an effect of relatedness. This was addressed in the study design by implementing a six month gap between times of testing, therefore reducing the likelihood that any speeded responses at time two were due to repetition priming. Secondly, detailed individual analysis allowed for comparison across the three experimental semantic tasks for PWA, and to performance on other language and cognitive tests, which is explored in Chapter 10.

6.7.3.1 Analysis of patterns of performance in PWA

To explore the effect of time of testing on response latency to targets, Wilcoxon Signed Rank Tests were conducted. For each PWA, the mean response latency to targets at time one was compared to the response latency to all targets at time two. If no differences were found, then this would support the null hypothesis that there is no difference between response latencies at time one and at time two of testing. Results are presented in Table 6.14, including mean difference response times, and results of nonparametric comparisons, with median response times in line with nonparametric test reporting.[15] Within the highlighted column of difference in mean response time between time 1 and 2 of testing, negative values indicate quicker response latencies to targets at time two, whereas positive values indicate slower response latencies to targets at time two.

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[15] Parametric analyses were also conducted and the same pattern of results and significance found; these can be viewed in Table O2 in Appendix O.

Table 6.14: Effect of time of presentation on response latency to targets in PWA (ms)

PWA	**Time 1 mean**	**Time 2 mean**	**Difference in mean from time 1 to time 2**	**Time 1 target median**	**Time 2 target median**	***n***	***z***	***p***	***r***
BT	1248 (319)	1213 (284)	-35	1138	1137	50	-0.01	.99	-
CW	971 (195)	878 (130)	-93	927	859	49	-3.15	.001***	.32
DB	914 (193)	891 (194)	-23	868	809	48	-0.90	.373	-
DH	1411 (506)	1508 (477)	97	1179	1370	40	-1.00	.324	-
DW	1041 (189)	1055 (228)	14	987	1042	41	-0.31	.761	-
FM	1983 (578)	1625 (326)	-358	1859	1612	35	-3.24	.001***	.39
GB	1137 (222)	1117 (244)	-20	1061	1044	41	-0.43	.673	-
JC	1394 (196)	1330 (154)	-64	1413	1296	43	-1.77	.077	-
JK	1251 (171)	1220 (295)	-31	1228	1177	49	-1.73	.083	-
JM	2669 (999)	1775 (449)	-894	2500	1611	47	-5.18	.000***	.53

PWA	Time 1 mean	Time 2 mean	Difference in mean from time 1 to time 2	Time 1 target median	Time 2 target median	*n*	*z*	*p*	*r*
LW	1014 (224)	1004 (159)	-10	977	954	50	-0.68	.500	-
NMH	1038 (107)	986 (120)	-52	1043	977	49	-2.11	.034*	.21
PG	1364 (375)	1787 (530)	432	1293	1612	47	-4.28	.000***	.44
PS	1377 (273)	1365 (294)	-12	1363	1294	43	-0.64	.530	-
RP	1350 (332)	928 (140)	-422	1293	927	49	-6.07	.000***	.61
RT	1396 (140)	1288 (340)	-108	1363	1228	46	-2.66	.007**	.28
SE	1480 (298)	1246 (237)	-234	1411	1178	49	-4.93	.000***	.50
SH	1136 (165)	1276 (195)	140	1113	1239	49	-3.54	.000***	.36
SL	1346 (195)	1256 (229)	-90	1312	1279	48	-2.58	.009**	.26
TS	1402 (421)	1346 (525)	-56	1246	1113	47	-1.10	.274	-

Note. Highlighted rows indicate the PWA with a main effect of relatedness condition. Standard deviation in brackets. *n* = number of targets entered into analysis; z = Wilcoxon Signed Rank Test; *p* = significance level, *r* = effect size.

***p ≤ .001. **p ≤ .01. *p ≤ .05.

For the four PWA with a significant effect of relatedness (significantly faster responses to targets in the related condition than in the unrelated condition), one PWA was slower at time two (DH) while three PWA were faster at time two (TS, GB, LW), however these differences in response latency between times of testing were not significant. This is illustrated in Figure 6.9, in which negative values indicate quicker response latencies to targets at time two, positive values indicate slower response latencies to targets at time two. This supports the null hypothesis of no difference in response latency to targets between time of testing, and therefore the claim that the main effect of relatedness shown by these PWA is due to a semantic priming effect.

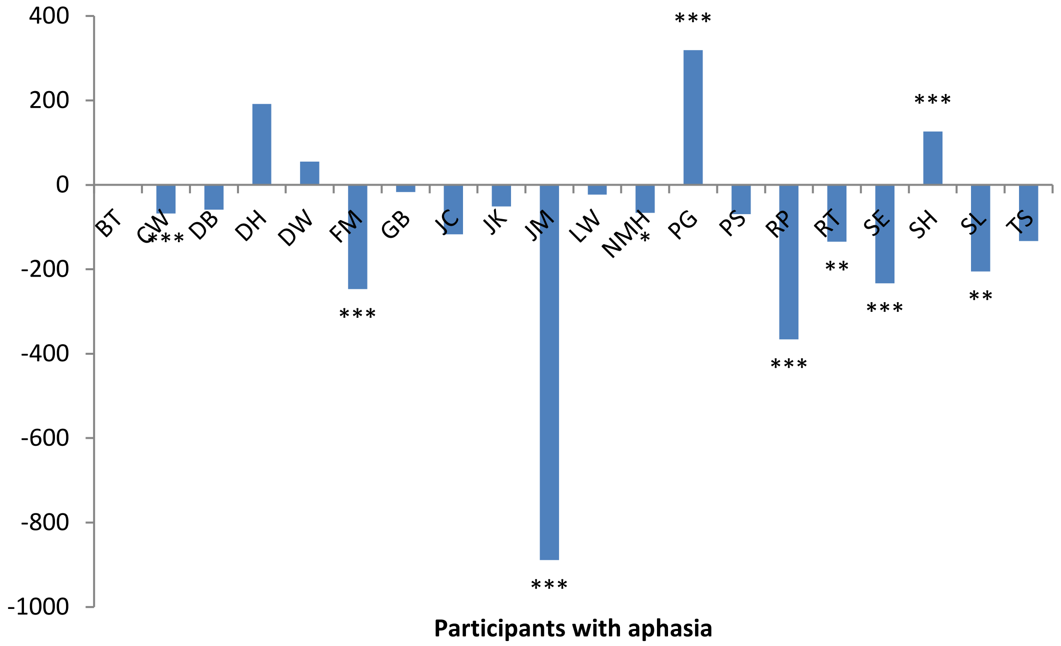

Figure 6.9: PWA difference in median response latency to targets in semantic priming time 1 to time 2.

Of the 16 PWA demonstrating no main effect of relatedness condition, three subgroups emerged: i) participants with significantly slower response latencies at time two (PG, SH); ii) participants with no significance difference in response latency to targets between time one and two (BT, DB, DW, JC, JK, PS); and iii) participants with significantly faster response latencies at time two (CW, FM, JM, NMH, RT, RP, SE, SL).

Practice effects or repetition priming effects influencing response latency can be ruled out for the first two subgroups: i) the two PWA who responded to targets significantly slower at time two compared to time one; ii) the six PWA for whom there was no significant difference in response latency between time one and two of testing. The final subgroup of eight participants demonstrated significantly faster response latencies at time two, which therefore could be accounted for by repetition priming or practice effects. However, as no PWA in this subgroup demonstrated a main effect of relatedness in the original analyses, the significant difference in response latency between time one and time two will not be further explored here.

6.7.4 Summary of PWA individual semantic priming analysis

Nineteen PWA responded faster in the related condition than in the unrelated condition and this was significant for four PWA, who demonstrated semantic priming with small effect sizes. Fourteen PWA responded faster in the semantically similar condition than in the associated condition, with six responding faster in the associated condition. The differences in response to the two different stimuli relationship types were not significant, indicating that for those four PWA with a main effect of relatedness, this was of the same magnitude for semantically similar and associated prime-targets pairs.

PWA were exposed to the same target items at time one and time two of testing, therefore repetition or practice effects could potentially have contributed to faster reaction times at time two, which could interfere with findings of semantic priming effects. Note, however, that as a six month gap between times of testing was implemented, the likelihood that speeded responses at time two were due to repetition priming is reduced. At a first level of analysis, individual response latencies to targets from time one to two were compared to investigate the effect of time. For the four PWA demonstrating a significant priming effect there was no significant difference in response latency between time one and two, indicating that speeded responses to targets in the related condition was a specific effect of semantic-associative priming and not a result of repetition priming or of practice effects. For the 16 participants with no main effect of relatedness condition, three subgroups emerged when considering the effect of time. For two groups there appeared to be no effect of repeated exposure or practice: two PWA presented with significantly slower response latencies at time two and six PWA presented with no significant difference in response latency to stimuli between times one and two. The third group of eight PWA presented with significantly faster response latencies at time two, however as they did not show semantic priming, this is not further examined here.

To summarise, for the four participants demonstrating a main effect of relatedness, it can be concluded that the main effect occurred as a result of semantic priming, and there was no impact of repetition priming or practice effects. Fifteen of the 16 other PWA demonstrated faster response latencies to targets in the related condition than in the unrelated condition, but this did not reach significance.

6.8 Semantic priming summary of results

The SP task was analysed within each group, between groups, and at an individual level for PWA. At the initial stage of within-group analysis, the PWA group demonstrated the same pattern of results as the control group. When results were analysed using the participant means, significant group semantic priming effects were found, which was the same effect independent of whether the prime was semantically similar to, or associated with, the target. When results were analysed using the item means, there was a trend towards faster response latencies to targets in the related prime condition than in the unrelated condition. However, this did not reach significance, possibly due to the limited sample size.

Between-group comparisons were subsequently completed. Participants with aphasia had completed the SP task on two separate occasions so that analysis at an individual level could be completed. However, so that valid, direct comparisons could be made between the two groups, only the PWA time one data were entered into the participant and item levels of analysis. A similar pattern of results was observed as in the within-group level of analyses of semantic priming. Overall the control group responded significantly faster than the PWA group in making lexical decisions, however when considering the effect of semantic priming, a trend for faster responses in the related condition was demonstrated equally for both groups; this reached significance at the participant level of analysis and was approaching significance at the item level.

When analysed individually, four individuals with aphasia presented with a significant semantic priming effect. For these participants, there was no significant difference in response latency from time one to time two of testing, suggesting that the semantic priming effect identified was not due to repetition priming. Fifteen of the remaining 16 PWA demonstrated a trend towards a semantic priming effect, and one individual did not. All PWA showed patterns of facilitation by a semantically similar prime, whereas only half showed facilitation by associated primes, the other half showing inhibition. Overall, 14 PWA demonstrated greater priming effects in the semantically similar condition than in the associated condition, and six showed greater effects in the associated condition. However, none of the differences in response to the different prime-target stimuli types reached significance. The results of the WPV task for both groups of participants are now considered in Chapter 7.

Chapter 7 Word to picture verification results

7.1 Introduction

In the current chapter, the results of the WPV task for control participants and PWA are described. Sections 7.2 and 7.3 present the descriptive statistics for accuracy and response latency respectively, and detail how the data were prepared prior to analysis. In section 7.4, the within-group investigations are presented with accuracy and response latency data analysed at the participant and item level for each group of participants. Within each level, effects of congruency condition (congruent or incongruent), and target-distractor relationship (semantically similar or associated) in the incongruent condition only, are explored. Section 7.5 describes the between-group analysis of the control group and PWA group accuracy and response latency using participant and item level data, again exploring the impact of congruency condition and stimuli relationship. Section 7.6 presents the effects of congruency on accuracy and response latency on individual PWA performance at the item level. Exact significance (2- tailed) is reported for all results unless otherwise stated.

7.2 Accuracy and error rates: data preparation and descriptive statistics

7.2.1 Data preparation

Responses were coded as accurate when participants correctly identified congruent or incongruent written target words and picture pairs. Incorrect responses were coded as errors and an accuracy score for congruent and incongruent conditions was generated for each participant.

7.2.2 Descriptive statistics

The spread of individual participant WPV accuracy scores can be viewed in Figure 7.1. Accuracy and error rates for targets presented in congruent and incongruent conditions are presented in Figure 7.1: Individual participant accuracy in the WPV task

Table 7.1 for control participants and Table 7.2 for PWA. Note that each control participant completed the task once, seeing each target in either the congruent or incongruent condition (*n*=50), whereas PWA completed the WPV task twice, seeing all 50 targets in both their congruent and incongruent conditions (*n*=100). In terms of descriptive statistics, the mean and standard deviation are provided, however in the non-parametric analysis the median is provided, in line with the requirements of non-parametric test reporting. Note that the distinction between semantically similar and associated pairs only applies to the incongruent condition, where a semantically similar or associated distractor word were presented with a target picture; in the congruent condition, the written word and picture were the same.

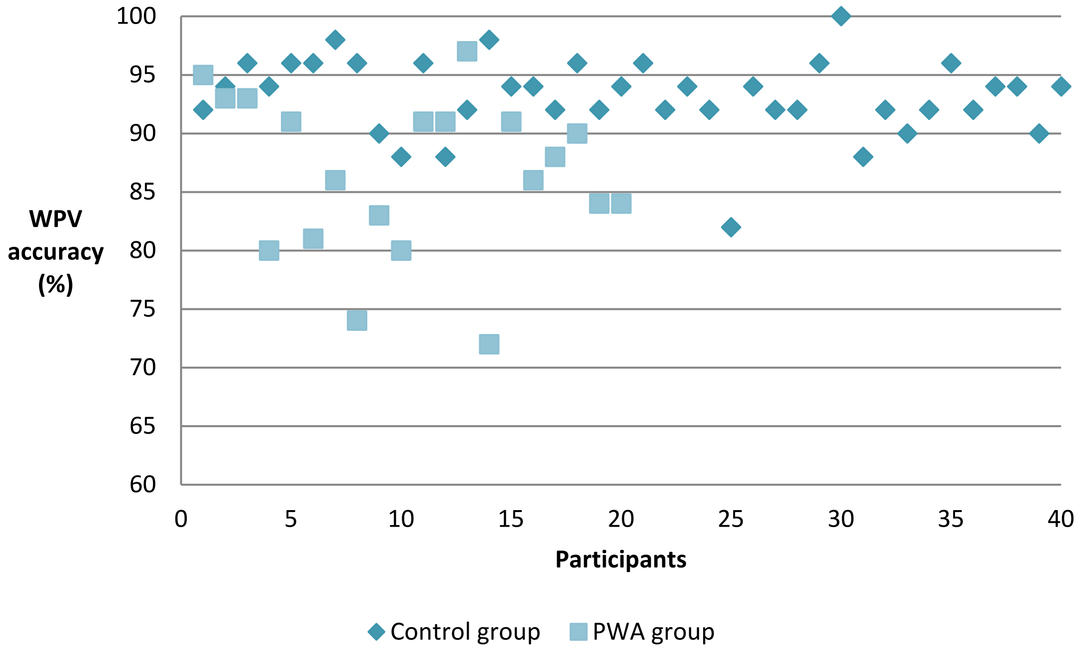

Figure 7.1: Individual participant accuracy in the WPV task

Table 7.1: Word to picture verification task: control group accuracy and error rates

	Control participant accuracy				**Control participant errors**			
	Mean	Mean proportion	Range	Range proportion	Mean	Mean proportion	Range	Range proportion
Congruent condition (25)	24.68 (.53)	.99	23-25	.92-1	0.33	.01	0-2	0-.08
Incongruent condition (25)	21.93 (1.56)	.88	16-25	.64-1	3.08	.03	0-9	0-.09
Semantically similar (16)	13.53 (1.04)	.85	10-16	.63-1	2.48	.15	0-6	0-.38
Associated (9)	8 (.84)	.93	6-9	.67-1	.6	.07	0-.03	0-.33
Total overall (50)	46.60 (1.65)	.93	41-50	.82-1	3.40	.07	0-9	0-.18

Note. Standard deviation in brackets.

Table 7.2: Word to picture verification task: PWA group accuracy and error rates

	PWA accuracy				**PWA errors**			
	Mean	Mean proportion	Range	Range proportion	Mean	Mean proportion	Range	Range proportion
Congruent condition (50)	48.40 (1.50)	.97	45-50	.90-1	1.60	.03	0-5	0-.10
Incongruent condition (50)	38.10 (6.74)	.76	23-47	.46-.94	11.90	.24	3-27	.06-.54
Semantically similar (32)	24.95 (4.05)	.78	14-31	.44-.97	7.05	.22	1-18	.03-.56
Associated (18)	13.15 (3.18)	.73	6-18	.33-1	4.85	.27	0-12	0-.67
Total overall (100)	86.50 (6.76)	.87	72-97	.72-.97	13.50	.14	3-28	.03-.28

Note. Standard deviation in brackets.

The data were inspected for trends in group performance. Both groups of participants provided more accurate responses in the congruent than incongruent condition. Overall, and in both conditions, the control group demonstrated higher accuracy than the PWA group. As illustrated in Figure 7.2, in the incongruent condition control participants demonstrated higher accuracy in the associated condition than in the semantically similar incongruent condition, whereas the PWA group showed the opposite pattern.

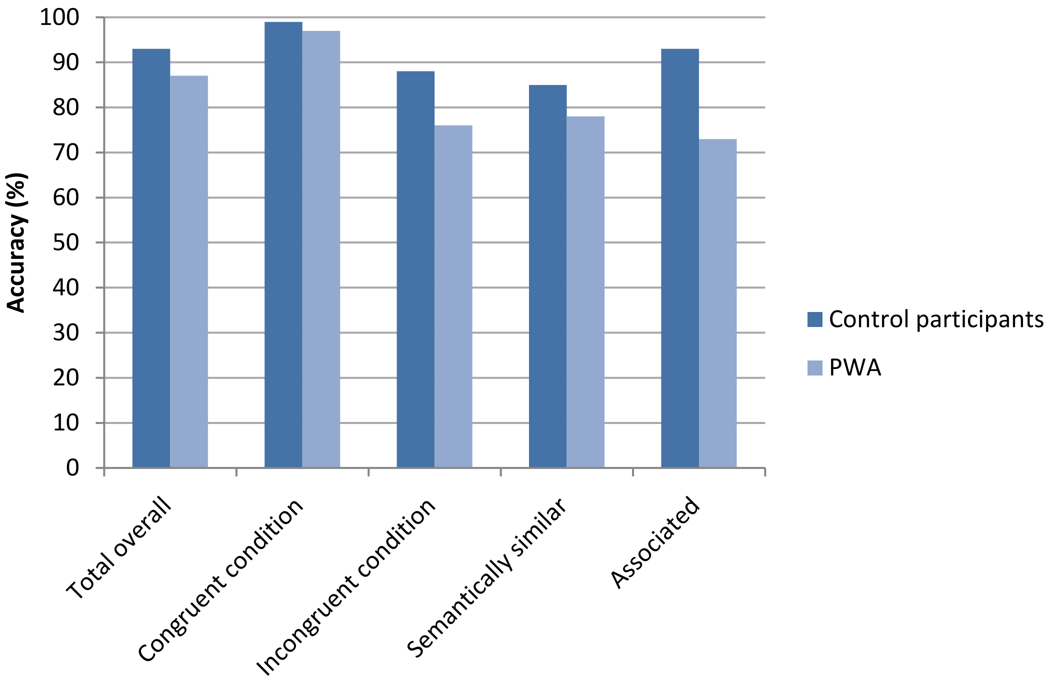

Figure 7.2: Control and PWA group accuracy in the WPV task

7.3 Response latency: data preparation and descriptive statistics

7.3.1 Data preparation

In the analysis of response latency, only data for correct responses were included, for all participants. There were no instances of premature responses, therefore unlike for the semantic priming (SP) task, no exclusionary cut-offs for responses made prior to 200ms were applied. Similarly, a response time cut-off was not applied when preparing the data for the control and PWA groups, as responses were not required to demonstrate unconscious processing as in the semantic priming. Any PWA responses over 10 seconds were kept in the analysis to provide a valid representation of the time required for PWA to make their decisions, whereas there were no control participant responses over 10 seconds.

For control participants and PWA, each participant's raw data were viewed and descriptive statistics generated. In the by-participant analyses, response latencies that deviated by more than two standard deviations from an individual participant's mean were replaced with the mean plus or minus two standard deviations, as appropriate. This process was applied separately for target stimuli paired with incongruent and congruent distractors. At the by-item level, each target item's mean and standard deviation were computed and where items' response latencies deviated more than two standard deviations from their mean, the value was replaced with the mean plus or minus two standard deviations.

7.3.2 Descriptive statistics

The spread of individual participant mean response latencies is presented in Figure 7.3. Overall response latencies are presented for the control group and PWA group, then separated into two tiers, i) congruent versus incongruent condition (Figure 7.3: Individual participant mean response latency in the WPV task Table 7.3); and ii) within the incongruent condition, whether the distractor was semantically similar to or associated with the target (Table 7.4).

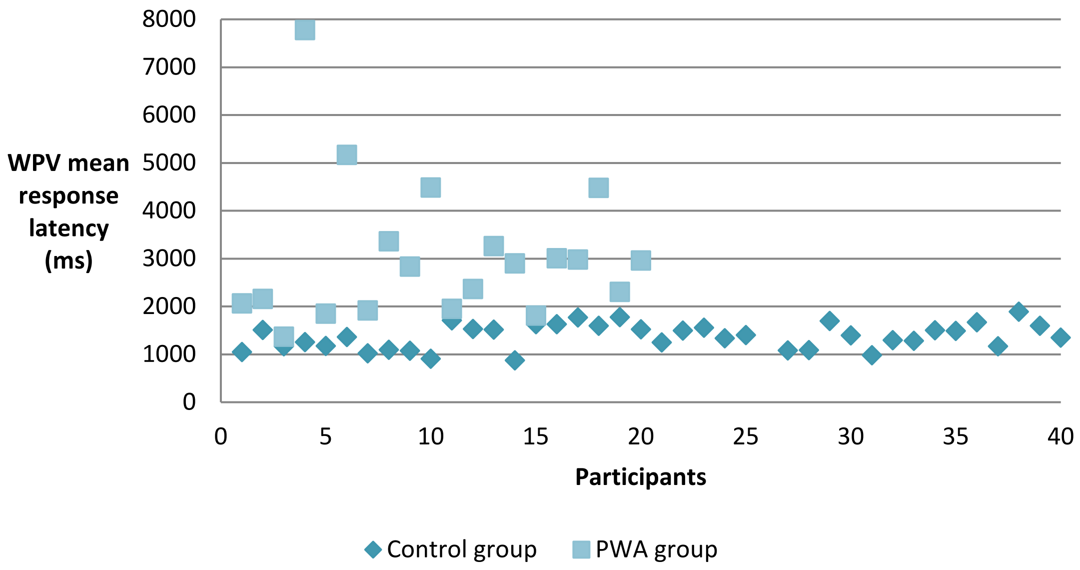

Figure 7.3: Individual participant mean response latency in the WPV task

Table 7.3: Group response latency to targets in the WPV task (ms)

	Control participants	PWA
Congruent condition(50)	1262 (248)	2370 (1250)
Incongruent condition (50)	1516 (304)	3739 (1790)
Mean overall (100)	1389 (304)	3187 (1901)
Difference between conditions	254	1369

Note. Standard deviation in brackets.

The control group demonstrated shorter response latencies overall and in both the congruent and incongruent distractor conditions. Both groups showed an advantage for the congruent condition and this was more marked for the PWA.

Response latency to targets in the incongruent condition are presented in Table 7.4 according to whether target presentation was preceded by a semantically similar distractor (for example, *pigeon* - *owl*), or an associated distractor (for example, *donkey* - *cart*).

Table 7.4: Response latency to targets in the WPV incongruent condition categorised by stimuli relationship (ms)

	Control participants	PWA
Semantically similar incongruent distractor (32)	1509 (315)	3655 (1761)
Associated incongruent distractor (18)	1513 (312)	3943 (2006)
Difference between distractor conditions	4	288

Note. Standard deviation in brackets.

Control participant response latency remained similar across the semantically similar and associated stimuli relationship conditions, whereas the PWA group were slower to respond to targets presented with an associated distractor.

7.4 WPV within-group comparisons – planned analysis

In this analysis the overall group accuracy and mean response latencies were investigated within the control group and the PWA group separately. Response latency and accuracy data for targets in the congruent and incongruent conditions were checked for normality of distribution at the by-participant and by-item levels of analysis for both the control and PWA groups. Kolmogorov-Smirnov tests demonstrated that the control group data were non-normally distributed for accuracy at the by-participant and by-item levels, and reaction time data were non-normally distributed at the by-item level, but normally distributed at the by-participant level. The PWA group data were non-normally distributed in all accuracy and reaction time categories except for accuracy for the incongruent condition at the by-participant level. As the PWA sample size was small, the data were not transformed and non-parametric tests were subsequently employed for all the data.

Control participant and PWA group data were analysed within-group for accuracy and response latency, at the participant and item levels. At the participant level, Wilcoxon Signed Rank tests were used to compare:

i) accuracy to targets in the congruent versus incongruent conditions;

ii) the effect of stimuli relationships (semantically similar versus associated) in the incongruent condition on accuracy;

iii) response latency to targets in the congruent versus incongruent conditions;

iv) the effect of stimuli relationships (semantically similar versus associated) on response latency in the incongruent condition.

At the item level, the same comparisons were completed to investigate the impact of the congruency condition on accuracy and response latency to targets. Mann-Whitney U Tests were used in the stimuli relationship analysis, as the items in each group were independent.

The by-participant repeated measures analysis involved a total accuracy score or mean response latency for each participant. At the item level of analysis, total accuracy scores and response latency means for each item were used, with the exception of the accuracy analysis of stimuli relationship; here proportion accuracy was used due to the different number of items within the semantically similar and associated conditions.

For the PWA by-participant response latency analysis of congruency condition, items were only included when individuals responded accurately in both the congruent and incongruent conditions. For example, if an error response was made for *cart* in the incongruent condition, but an accurate response was given in the congruent condition, the congruent response latency for *cart* was also removed from the analysis as full data were not available for that target item. In the by-item analysis, error pairs were not removed, as the item mean was being considered between participants rather than within participants.

7.4.1 WPV within-group results: accuracy

Within-group accuracy comparisons of the congruent versus incongruent conditions are presented in Table 7.5 by-participant and in Table 7.6 by-item. Table 7.7 and Table 7.8 present the comparison of accuracy in the presence of semantically similar and associated distractors in the incongruent condition, for participant and item levels respectively. Please refer back to Figure 7.2 for mean proportion accuracy and illustration of the difference in group performance.

Table 7.5: By-participant congruency condition comparisons of accuracy

	Congruent median	Incongruent median	*z*	*p*	*r*
Control group	25.0	22.0	5.41	.000***	.61
PWA group	48.5	38.5	-3.93	.000***	.62

Note. z = *z* statistic from Wilcoxon Signed Ranks Test; *p* = significance level; *r* = effect size. ****p* ≤ .001.

Table 7.6: By-item congruency condition comparisons of accuracy

	Congruent median	Incongruent median	*z*	*p*	*r*
Control group	19.5	18.0	-2.28	.022*	.23
PWA group	20	16.5	-5.30	.000***	.53

Note. z = *z* statistic from Wilcoxon Signed Ranks Test; *p* = significance; *r* = effect size. ****p* ≤ .001. **p* ≤ .05.

Table 7.7: By-participant stimuli relationship comparisons of accuracy in the incongruent condition

	Semantically similar median (%)	Associated median (%)	*z*	*p*	*r*
Control group	.88	1.00	-4.38	.000***	.49
PWA group	.78	.70	-1.45	.153	-

Note. z = *z* statistic from Wilcoxon Signed Ranks Test; *p* = significance level; *r* = effect size.
****p* ≤ .001.

Table 7.8: By-item stimuli relationship comparisons of accuracy in the incongruent condition

	Semantically similar median (proportion correct)	Associated median (proportion correct)	*U*	*z*	*p*
Control group	.98	.95	279	-0.19	.853
PWA group	.85	.78	248	-0.81	.423

Note. *U* and *z* = Mann-Whitney U test statistics; *p* = significance.

At the participant level, control participants and PWA were both significantly more accurate at responding to targets in the congruent condition than in the incongruent condition with a large effect size for both cohorts (Cohen, 1988). The same pattern was apparent at the item level of analysis, but with a small effect size for control participants and a large effect size for PWA.

At the participant level, the control group were significantly more accurate in responding to targets in the presence of an associated distractor, compared to when there were semantically similar distractors. The opposite pattern however, was demonstrated for PWA, who showed greater accuracy with semantically similar distractors, which did not reach significance. At the item level, both groups were more accurate in responding to targets in the incongruent condition in the presence of a semantically similar distractor; however this trend was non-significant.

7.4.2 WPV within-group results: response latency

Within-group response latency comparisons of the congruent versus incongruent conditions are displayed in Table 7.9 and Table 7.10 for participant and item levels of analysis respectively. Effects of stimuli relationship on response latency to targets in the incongruent condition are shown in Table 7.11 and Table 7.12.

Table 7.9: By-participant congruency condition comparisons of response latency

	Congruent median	Incongruent median	*z*	*p*	*r*
Control group	1292	1576	-5.51	.000***	.62
PWA group	1973	3473	3.92	.000***	.62

Note. z = *z* statistic from Wilcoxon Signed Ranks Test; *p* = significance level; *r* = effect size.
****p* ≤ .001.

Table 7.10: By-item congruence condition comparisons of response latency

	Congruent median	Incongruent median	*z*	*p*	*r*
Control group	1228	1461	-4.96	.000***	.50
PWA group	2150	3574	5.46	.000***	.55

Note. z = *z* statistic from Wilcoxon Signed Ranks Test; *p* = significance; *r* = effect size.
****p* ≤ .001.

Control participants and PWA demonstrated significantly faster response latencies to targets in the congruent condition than to those in the incongruent condition, at both the participant and item levels of analysis, with large effect sizes for all comparisons.

Table 7.11: By-participant stimuli relationship comparisons of response latency in the incongruent condition

	Semantically similar median	Associated median	*z*	*p*
Control group	1531	1556	-0.16	.879
PWA group	3411	3386	-1.16	.261

Key*: z* = *z* statistic from Wilcoxon Signed Ranks Test; *p* = significance level.

Table 7.12: By-item stimuli relationship comparisons of response latency in the incongruent condition

	Semantically similar median	Associated median	*U*	*z*	*p*
Control group	1446	1490	286	-.04	.976
PWA group	3460	3621	283	-.10	.928

Note. *U* and *z* = Mann-Whitney U test statistics; *p* = significance; *r* = effect size.

Neither group showed a significant difference in response latency to targets presented with a semantically similar versus associated distractor in the incongruent condition, at the both the participant and item levels of analysis.

7.4.3 Summary of group performance

Similar results were found for control participants and PWA. At both the participant and item levels of analysis, participants responded significantly faster and more accurately to targets in the congruent condition than to targets in the incongruent condition. At the participant level, the control group were significantly more accurate in the associated incongruent condition, whereas the PWA group demonstrated a trend to greater accuracy in the semantically similar condition, which did not reach significance. At the item level of analysis, both groups showed a trend for increased accuracy in the semantically similar incongruent condition, which did not reach significance for either group.

The same pattern of results was demonstrated for both groups with regard to the response latency analyses. At both the participant and item levels of analysis, the control and PWA groups showed significantly faster response latencies to targets in the congruent condition compared to the incongruent condition, and there was no effect of target-distractor relationship on response latency.

7.5 WPV between-group comparison – planned analysis

The two groups of participants were subsequently compared for accuracy; analysis was conducted at the participant and item levels. At both levels of analysis, the control group data were compared to the time 1 and time 2 PWA data; otherwise, there were very small numbers in each condition.[16] Also, repetition priming effects were not of concern in this task, unlike in the Semantic Priming task, in which brief semantic priming effects were being measured. Proportional accuracy totals were used to enable comparison between groups.

Comparisons of congruence condition were made between the control participant group and PWA group accuracy data, using unrelated Mann-Whitney U Tests for the participant level, and related Wilcoxon signed ranks test at the items levels of analysis, including:

i) targets in the congruent conditions;
ii) targets in the incongruent conditions.

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[16] Group comparisons were also conducted using PWA time 1 data only, and the same results of significance were found.

To compare effects of distractor-stimuli relationship in the incongruent condition on between-group accuracy, unrelated Mann-Whitney U tests were conducted for participant and item levels of analysis, due to the different participants or items within each comparison. Comparisons were made for:

ii) targets appearing in the semantically similar incongruent condition;
iv) targets appearing in the associated incongruent condition.

Results are presented for accuracy in section 7.5.1. The same analyses were repeated for response latency, presented in section 7.5.2.

As non-parametric tests had been used for the between-group comparison, the difference in effect of congruency and stimuli relationship between the two groups was subsequently analysed using independent samples Mann-Whitney U Tests, for both accuracy and response latency. This was computed at the participant and item levels to compare the difference in congruency effect between groups. The difference in stimuli relationship effects between groups was analysed at the participant level only.

7.5.1 Between-group: WPV accuracy results

Between-group comparisons of accuracy data across congruency conditions at participant and item levels, are presented in Table 7.13. Table 7.14 shows the between-group comparisons of target accuracy, when in the presence of semantically similar and associated distractors (in the incongruent condition only).

Table 7.13: Between-group analyses of WPV accuracy: congruent vs. incongruent condition

	Accuracy						
	Control median	PWA median	*n*	*U*	*z*	*p*	*r*
By-participant							
Congruent condition	1.00	.97	60	245	-2.73	.006**	.35
Incongruent condition	.88	.77	60	178	-3.52	.000***	.45
By-item							
Congruent condition	19.5	20	100	-	-1.43	.152	-
Incongruent condition	18.0	16.5	100	-	-3.51	.000***	.35

Note. *n* = number of stimuli; *U* and *z* = Mann-Whitney U test statistics (by-participant) *z* = statistic from Wilcoxon Signed Ranks Test (by-item); *p* = significance level; *r* = effect size.
****p* ≤ .001. ***p* ≤ .01.

At the participant level the control group was significantly more accurate than the PWA group in both the congruent and incongruent conditions, with medium effect sizes for both comparisons, as shown by the value of *r* (Cohen, 1988). At the item level, there was no significant difference in accuracy between control and PWA groups in the congruent condition. The control group was significantly more accurate at responding to targets in the incongruent condition than the PWA group, with a medium effect size.

Table 7.14: Between-group comparison of WPV accuracy: semantically similar and associated incongruent conditions

	Accuracy						
	Control median	PWA median	*n*	*U*	*z*	*p*	*r*
By-participant							
Semantically similar	.88	.81	60	256	-2.32	.019*	.30
Associated	1.00	.72	60	113	-4.71	.000***	.61
By-item							
Semantically similar	18.0	17.0	64	356	-2.12	.034*	.27
Associated	18.0	15.5	36	73	-2.85	.004**	.47

Note. n = number of stimuli; *U* and *z* = Mann-Whitney U test statistics; *p* = significance level; *r* = effect size.
****p* ≤ .001. **p≤ .01. **p* ≤ .05.

At the participant level of analysis the control group was significantly more accurate than the PWA group when responses were considered in both the semantically similar and associated incongruent conditions, with medium and large effect sizes, respectively. At the item level of analysis control participants were significantly more accurate than the PWA group at responding to targets in the semantically similar and associated incongruent conditions, with small and medium effect sizes respectively.

7.5.1.1 Difference scores between-groups: accuracy

Table 7.15 displays the results of the between-group comparison of the difference in accuracy between congruent and incongruent conditions i.e. does the difference in conditions differ significantly between the control and PWA group? Table 7.16 displays the comparison of group difference in accuracy to semantically similar and associated pairs in the incongruent condition.

Table 7.15: Between-group comparison of difference in WPV accuracy: congruency conditions

	Accuracy						
	Control median	PWA median	*n*	*U*	*z*	*p*	*r*
By-participant							
Congruency difference	.10	.20	60	211	-3.00	.002**	.39
By-item							
Congruency difference	3	3	100	991	-1.79	.073	-

Note. *n* = number of stimuli; *U* and *z* = Mann-Whitney U test statistics; *p* = significance level; *r* = effect size.
**$p \leq .01$.

Table 7.16: Between-group comparison of difference in WPV accuracy: stimuli relationship

	Accuracy					
	Control median	PWA median	*n*	*U*	*z*	*p*
By-participant						
Stimuli relationship difference	2	-41	60	311	-1.40	.165

Note. *n* = number of stimuli; *U* and *z* = Mann-Whitney U test statistics; *p* = significance level.

At the participant level, the PWA group showed a significantly bigger difference between congruent and incongruent accuracy than the control group, with a medium effect size. This was approaching significance at the item level. No significant difference was present between groups in the difference in accuracy to semantically similar versus associated targets in the incongruent condition.

7.5.2 Between-group WPV response latency results

Between-group comparisons of congruency at the participant and item levels are presented in Table 7.17 for response latency in each congruence condition. Table 7.18 presents the between-group comparisons for semantically similar and associated incongruent condition response latency.

Table 7.17: Between-group analyses of WPV response latency: congruent vs incongruent condition

	Response latency						
	Control median	PWA median	*n*	*U*	*z*	*p*	*r*
By-participant							
Congruent condition	1292	1926	60	62	-5.30	.000***	.68
Incongruent condition	1576	3458	60	21	-5.94	.000***	.77
By-item							
Congruent condition	1228	2150	100	-	-6.15	.000***	.62
Incongruent condition	1461	3574	100	-	-6.15	.000***	.62

Note. n = number of stimuli; *U* and *z* = Mann-Whitney U test statistic (by-participant); *z* = statistic from Wilcoxon Signed Ranks Test (by-item); *p* = significance level; *r* = effect size.
****p* ≤ .001.

The control group demonstrated significantly faster reaction times than the PWA group in both the congruent and incongruent conditions, and at both the participant and item levels, with large effect sizes across all comparisons (Cohen, 1988).

Table 7.18: Between-group analyses of WPV response latency: semantically similar and associated incongruent conditions

	Response latency						
	Control median	PWA median	*n*	*U*	*z*	*p*	*r*
By-participant							
Semantically similar	1531	3411	60	21	-5.94	.000***	.77
Associated	1556	3376	60	18	-5.99	.000***	.77
By-item							
Semantically similar	1446	3460	64	11.00	-6.73	.000***	.84
Associated	1490	3621	36	0.00	-5.13	.000***	.85

Note. n = number of stimuli; *U* and *z* = Mann-Whitney U test statistics; *p* = significance level; *r* = effect size.
****p* ≤ .001.

The control group demonstrated significantly faster reaction times than the PWA group when compared across both the semantically similar and associated incongruent conditions, and at the participant and item levels, with large effect sizes for all (Cohen, 1988).

7.5.2.1 Difference scores between groups: response latency

Between-group comparisons of the difference in response latency between congruent and incongruent conditions are presented in Table 7.19. This examines if the magnitude in reaction time difference between conditions differed significantly between the control and PWA groups. The between-group comparison of difference in response latency to semantically similar and associated pairs in the incongruent condition is shown in Table 7.20.

Table 7.19: Between-group comparison of difference in WPV response latency: congruency conditions

	Response latency						
	Control median	PWA median	*n*	*U*	*z*	*p*	*r*
By-participant							
Congruency difference	212	1241	60	13	-6.07	.000***	.78
By-item							
Congruency difference	237	1259	100	509	-5.11	.000***	.51

Note. n = number of stimuli; *U* and *z* = Mann-Whitney U test statistics; *p* = significance level; *r* = effect size.
***$p \leq .001$.

Table 7.20: Between-group comparison of difference in WPV response latency: stimuli relationship

	Response latency						
	Control median	PWA median	*n*	*U*	*z*	*p*	*r*
By-participant							
Stimuli relationship difference	-.10	.07	60	151	-3.92	.000***	.39

Note. n = number of stimuli; *U* and *z* = Mann-Whitney U test statistics; *p* = significance level; *r* = effect size.
***$p \leq .001$.

The difference between the congruent and incongruent conditions is significantly greater for the PWA group at both the participant and item levels of analysis, with large effect sizes for both comparisons. The stimuli relationship difference is significantly greater for the PWA group, with a medium effect size. The PWA group responded faster to items in the associated incongruent condition, whereas the control group responded faster to items in the semantically similar incongruent condition; however this difference was larger for the PWA group.

7.5.3 Summary of between-group comparison

In the congruent condition, the control group was significantly more accurate than the PWA group at the participant level of analysis, but no significant difference between groups was present at the item level. In the incongruent condition, the control group was significantly more accurate than the PWA group at both levels of analysis. The control group remained significantly more accurate than the PWA group when accuracy was compared for semantically similar and associated incongruent conditions. The congruency effect of accuracy (the difference between incongruent and congruent conditions) was significantly larger for the control group at the participant level, and this trend approached significance at the item level. Accuracy in the semantically similar and associated incongruent conditions was not significantly different between groups.

The control group responded significantly faster than the PWA group in congruent and incongruent condition, at both the participant and item levels of analysis. This processing advantage remained when targets were compared in their semantically similar and associated incongruent conditions, at both the participant and item levels.

The congruency effect (i.e. the difference in response time between the congruent and incongruent conditions) was significantly greater for the PWA group than the control group, at both the participant and item levels of analysis. The PWA group appeared to be more sensitive to the effects of distractor stimuli relationship, as demonstrated by their significantly greater difference in response latency between distractor stimuli contexts than the control group, responding faster to items in the associated incongruent condition.

Now in section 7.6, individual WPV performance is explored at the item level, for both accuracy and response latency.

7.6 Individual PWA: by-item analyses

7.6.1 Individual PWA: accuracy planned analyses

Analysis of participant accuracy was carried out using McNemar's test, with accuracy compared at the two levels of congruence (congruent and incongruent conditions). To investigate the relationship between accuracy and distractor relationship (semantically similar or associated) in the incongruent condition, Chi square tests were used, and are reported as Fisher's Exact Test, as more than 20% had frequencies under five. For accuracy responses in the incongruent condition, Binomial Tests were applied to investigate if PWA were performing above chance level; these are reported as one-tailed significance levels.[17] To consider individual yes or no response bias in the WPV task, d-prime is also reported.

7.6.1.1 Individual PWA: accuracy results

Comparison of individual PWA accuracy in the congruent and incongruent conditions is presented in Table 7.21 for effects of congruence condition and Table 7.22 for effects of stimuli relationship. Full details of individual accuracy analyses can be viewed in Table P1 in Appendix P.

Table 7.21: Effect of WPV congruence on individual PWA accuracy

PWA	**Congruent target accuracy (50)**	**Incongruent target accuracy (50)**	**McNemar *p* value**	**Binomial Test exact - incongruent accuracy**	***d'* value (sensitivity)**	***C* value (response bias)**
BT	48	47	1.00	<.001***	3.305	-.098
CW	48	45	.453	<.001***	3.032	-.235
DB	50	43	.016*	<.001***	3.407	-.623
DH	45	35	.031*	.003**	1.806	-.379
DW	46	45	1.00	<.001***	2.687	-.062
FM	46	35	.019*	.003**	1.929	-.440
GB	50	36	.000***	.001***	2.909	-.872
JC	50	24	.000***	**.444**	2.276	-1.188
JK	48	35	.002**	.003**	2.275	-.613
JM	50	30	.000***	**.101**	2.580	-1.037
LW	50	41	.004**	<.001***	3.242	-.705
NMH	49	42	.039*	<.001***	3.048	-.530
PG	50	47	.250	<.001***	3.881	-.386
PS	49	23	.000***	**.336**	1.953	-1.077
RP	49	42	.039*	<.001***	3.048	-.530
RT	48	38	.006**	<.001***	2.457	-.522
SE	49	39	.006**	<.001***	2.826	-.641
SH	48	42	.070	<.001***	2.745	-.378
SL	48	36	.004**	.001***	2.334	-.584
TS	47	37	.013*	<.001***	2.198	-.456

Note. Underscore and **emboldened** represents accuracy not above chance.
****p* ≤ .001. ***p* ≤ .01. **p* ≤ .05.
d' = d prime. *C* = criterion measure.

All PWA performed with greater accuracy in the congruent WPV condition, which reached significance for fifteen participants. The non-significant Binomial Test results for three participants (JM, JC, PS) demonstrate that their responses in the incongruent condition were not above chance. The d-prime discrimination value assesses how well the congruent and incongruent conditions were distinguished, with a value of 0 representing no discrimination; DH, FM and PS present with the lowest values. All PWA show negative values of *C* (criterion

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[17] Two-tailed significance was also trialled, and the profile of results was found to be the same.

measures) suggesting some bias to yes responses, with JC and PS presenting with the largest values falling above 1.

Table 7.22: Effect of WPV stimuli relationship on individual PWA accuracy

PWA	Semantically similar condition accuracy (32)	Semantically similar Binomial Test exact	Associated condition accuracy (18)	Associated Binomial Test exact	χ^2	*p*
BT	31	<.001***	16	.001***	.271	.291
CW	27	<.001***	18	<.001***	1.63	.145
DB	27	<.001***	16	.001***	.000	1.000
DH	24	.004**	11	.240	.500	.348
DW	28	<.001***	17	<.001***	.087	.642
FM	23	.010**	12	.119	.004	.754
GB	23	.010**	13	.048*	.000	1.000
JC	18	.298	6	.119	1.593	.149
JK	24	.004**	11	.24	.500	.348
JM	22	.025*	8	.407	1.913	.134
LW	26	<.001***	15	.004**	.000	1.000
NMH	27	<.001***	15	.004**	.000	1.000
PG	31	<.001***	16	.001***	.271	.291
PS	14	.298	9	.593	.017	.771
RP	26	<.001***	16	.001***	.093	.694
RT	26	<.001***	12	.119	.663	.309
SE	26	<.001***	13	.048*	.148	.494
SH	29	<.001***	13	.048*	1.695	.118
SL	25	.001***	11	.240	.918	.325
TS	22	.025*	15	.004**	.628	.328

Note. χ^2 = Chi-square statistic; *p* = Fisher's exact test of significance.
****p* ≤ .001. ***p* ≤ .01. **p* ≤ .05.

No PWA demonstrated an effect of stimuli relationship on accuracy, performing with equal accuracy for semantically similar and associated targets. The Binomial Tests demonstrate that two PWA (JC, PS) did not perform above chance in the semantically similar incongruent condition, whereas eight PWA did not perform above chance in the associated incongruent condition (DH, FM, JC, JK, JM, PS, RT, SL).

7.6.2 Individual PWA: response latency analysis

Effect of congruence condition on individuals' response latency was investigated using a related samples Wilcoxon Signed Ranks Test with two conditions, congruent and incongruent, and the same targets appearing in each condition. The effect of stimuli relationship on response latency in the incongruent condition was explored using independent samples Mann-Whitney U tests, as different targets were present in each category.

7.6.2.1 Individual PWA: response latency results

Two levels of individual PWA analysis are presented. The effects of congruence condition (congruent vs incongruent) on response latency are shown in Table 7.23. The effects of distractor stimuli (semantically similar vs associated) on response latency in the incongruent condition are displayed in Table 7.24.

Table 7.23: Effect of WPV congruence on individual PWA response latency (ms)

PWA	**Congruent condition (median)**	**Incongruent condition (median)**	***n***	***z***	***p***	***r***
BT	1540	2127	90	-3.17	.001***	.33
CW	1305	1690	86	-2.43	.014*	.26
DB	1054	1489	86	-5.17	.000***	.56
DH	4018	6610	62	-2.47	.012*	.31
DW	1556	1874	82	-3.25	.001***	.36
FM	2293	5673	62	-3.27	.001***	.42
GB	1238	2209	72	-4.71	.000***	.56
JC	1707	4326	48	-4.29	.000***	.62
JK	1858	2493	66	-3.87	.000***	.48
JM	2427	4786	60	-3.96	.000***	.51
LW	1674	1925	82	-4.00	.000***	.44
NMH	1439	2929	82	-4.84	.000***	.53
PG	2293	2862	94	-2.01	.044*	.21
PS	1791	3548	46	-4.02	.000***	.59
RP	1356	2059	82	-4.80	.000***	.53
RT	1925	2627	74	-3.69	.000***	.43
SE	2477	2979	76	-1.73	.084	-
SH	2560	3748	82	-2.78	.005**	.31
SL	1966	2393	68	-2.44	.014*	.30
TS	1540	2427	70	-3.13	.001***	.37

Note. *n*= number of stimuli included in analysis; *z* = *z* statistic from Wilcoxon Signed Ranks Test; *r* = effect size.
p ≤ .001. **p ≤ .01. *p ≤ .05.

All PWA were slower at responding to targets in the incongruent condition than the congruent condition, which reached a significance for all participants except SE. Of these nineteen participants, 7 demonstrated large effect sizes, 10 a medium effect size and two a small effect size.

Table 7.24: Effect of WPV stimuli relationship on individual PWA response latency (ms)

PWA	**Semantically similar (median)**	**Associated (median)**	***U***	***z***	***p***	***r***
BT	2293	2059	189	-1.02	.317	-
CW	1674	1749	176	-1.206	.235	-
DB	1423	1490	211	-.126	.911	-
DH	6046	6808	72	-.903	.386	-
DW	1858	1975	172	-.623	.547	-
FM	5037	6986	94	-.811	.435	-
GB	2042	2493	120	-.972	.344	-
JC	4016	5455	31	-1.533	.137	-
JK	2427	2803	90	-.979	.343	-
JM	4886	3489	55	-1.548	.129	-
LW	1983	1925	148	-1.272	.211	-
NMH	3054	2862	190	-.135	.904	-
PG	2744	3514	215	-.741	.470	-
PS	3749	3230	43	-1.26	.224	-
RT	2560	2928	134	-.299	.781	-
RP	1807	2201	151	-1.31	.197	-
SE	2920	3046	155	-.031	.988	-
SH	3480	5137	97	-2.206	.027*	.34
SL	2452	2017	86	-1.285	.209	-
TS	2678	2125	127	-.546	.601	-

Note. *U* and *z* = Mann-Whitney U test statistics; *p* = significance; *r* = effect size.
**p* ≤ .05.

The Mann-Whitney U tests revealed no significant effect of stimuli relationship on target response latency for nineteen PWA. SH, however, demonstrated a significant effect, responding significantly slower to target pictures presented with an associated word than to targets presented with a semantically similar word, with a medium effect size.

7.6.3 Summary of individual PWA results

All PWA were more accurate in the congruent condition than in the incongruent condition - this was significant for 15 participants. In the incongruent condition as a whole, three PWA were responding at chance. In the incongruent condition, no individuals showed a significant difference between accuracy of responses to targets presented with semantically similar or associated distractors, demonstrating no effect of stimuli relationship on response accuracy. In the semantically similar incongruent condition two participants performed below chance, while eight performed below chance in the associated incongruent condition.

All PWA were significantly quicker at responding to targets in the congruent condition than in the incongruent condition, with the exception of one participant, for whom the processing advantage in the congruent condition did not reach significance (SE). In the incongruent condition, there was no difference between response latency in the semantically similar and the associated distractor conditions for PWA, with the exception of SH who was significantly slower at responding to targets with associated distractors than to those with semantic distractors.

7.7 Word to picture verification summary

Within-group analysis showed both control participants and PWA demonstrated similar patterns of performance at the by-participant and by-item levels: responses were significantly more accurate and faster in the congruent condition than in the incongruent condition, with no difference in response latency between the semantically similar and associated incongruent conditions. The control group was more accurate in the associated condition than in the semantically similar condition, but the PWA group showed similar accuracy across both conditions.

Between-group comparisons at the participant level showed that the control group was significantly more accurate and faster to respond than the PWA group in the congruent and incongruent conditions, and for both semantically similar and associated stimuli within the incongruent condition. At the item, level there was no difference between control and PWA accuracy to targets in the congruent condition; however, the control group made more accurate responses than the PWA group in the incongruent condition, possibly suggesting that at this level of analysis in the WPV task, semantic deficits are only detected via the incongruent condition. Control participants responded faster than PWA when responding to targets in both the congruent and incongruent conditions. When the semantically similar and associated incongruent distractor conditions were considered, control participants were significantly more accurate and faster at responding to targets with both of these distractor relationships than the PWA group.

When PWA were analysed individually at a by-item level, fifteen individuals followed the same pattern as control participants of providing more accurate responses in the congruent condition than in the incongruent condition; however, this pattern did not reach significance for the five other PWA who had similar high scores in each condition. In the incongruent condition, three PWA performed below chance level.

None of the PWA demonstrated a statistically significant difference in accuracy to targets dependent on their presentation with semantically similar or associated distractors in the incongruent condition; this was the same pattern as seen in the control group. Two PWA performed at chance level in the semantically similar incongruent condition, whereas eight performed at chance level in the associated incongruent condition (there were fewer items within this category however, which may have affected the outcome). Nineteen PWA were significantly quicker at responding to targets in the congruent condition than in the incongruent condition. Nineteen PWA showed no significant difference in speed of response to targets in the semantically similar or associated incongruent conditions.

Individual PWA performance is directly compared to the control group in section 9.3. Chapter 8 now details the results of the WPM task analysis for control and PWA groups.

Chapter 8 Word to picture matching results

8.1 Introduction

This chapter presents the results of the WPM task for control participants and PWA. Accuracy and response latency data are described in sections 8.2 and 8.3 respectively. Within and between-group comparisons are subsequently presented in sections 8.4 and 8.5. The within-group comparison includes consideration of stimuli relationship i.e. whether a semantically similar or associated distractor appear in the array of distractors. For ease of interpretation, the 32 semantically similar distractors and 18 associated distractors will be referred to as a *semantic* distractor group when exploring errors made in this overarching category, and then subcategorised in subsequent analyses. Finally, individual PWA descriptive statistics are presented in comparison to the control group; statistical analyses on the individual PWA data are reported in Chapter 9. Exact significance (2- tailed) is reported throughout.

8.2 Accuracy and errors rates: data preparation and descriptive statistics

8.2.1 Data preparation

Unlike the SP and the WPV tasks, all participants completed all 50 targets in the WPM task. Responses were coded as correct if the participant chose the picture that matched the written word, with incorrect responses coded as errors[18]. Accuracy data included the total number of accurate responses and an error analysis of the distractors which participants selected inaccurately, including semantically related, phonologically related or unrelated stimuli.

8.2.2 Descriptive statistics: accuracy

The spread of individual participant WPM accuracy is illustrated in Figure 8.1. Table 8.1 presents control group and PWA group overall accuracy and errors rates.

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[18] There was one instance of computer program error (freezing) in which a single participant response was recorded as a no response within the timing threshold and is omitted from analyses.

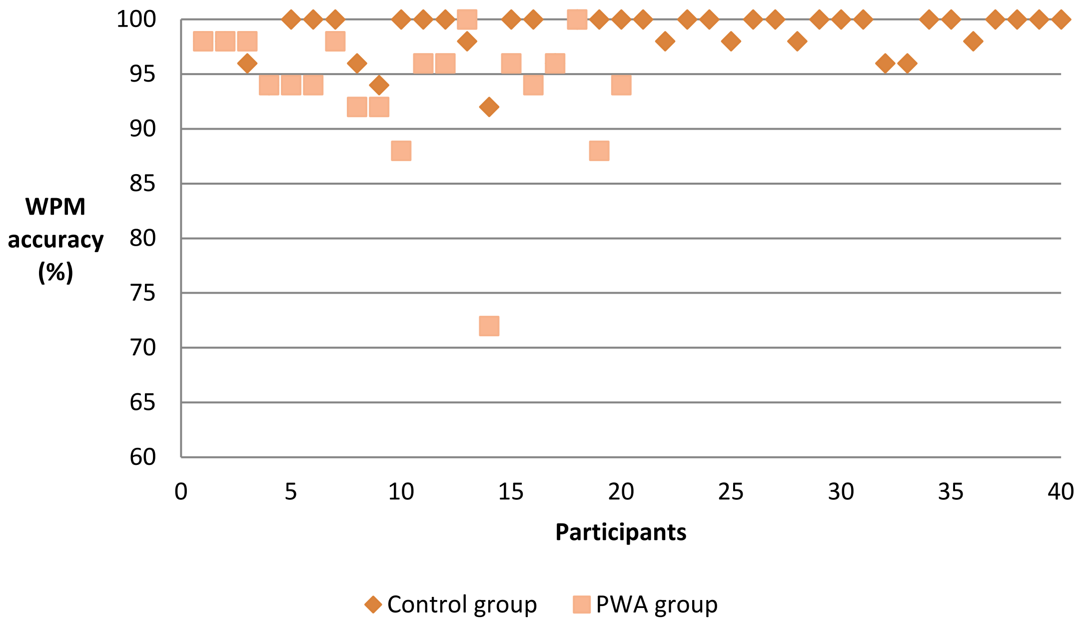

Figure 8.1: Individual participant WPM accuracy

Table 8.1: Overall accuracy and error rates

	Accuracy		Errors	
	Mean	Range	Mean	Range
Control group	49.33 (1.05)	46-50	.68 (1.05)	0-4
PWA group	46.95 (3.07)	36-50	3.05 (3.07)	0-14

Note. Standard deviation in brackets.

The WPM error pattern within each category is presented below in Table 8.2. Response patterns are then presented in Table 8.3 for the arrays in which a semantically similar distractor or associated distractor was present. For full breakdown of the mean and proportion of errors in each subcategory of error responses see Appendix Q.

Table 8.2: Breakdown of response patterns by stimuli category

		Target	Semantic	Phonological	Unrelated	No response
Control group (*n* = 40)	Mean	49.33 (1.05)	.58 (.98)	.05 (.22)	.03 (.16)	.03 (.16)
	Range	46-50	0-4	0-1	0-1	0-1
PWA group (*n* = 20)	Mean	46.95 (3.07)	2.30 (2.18)	.55 (.83)	.20 (.52)	-
	Range	36-50	0-9	0-3	0-2	-

Note. Standard deviation in brackets.

Table 8.3: Breakdown of responses by semantically similar or associated distractor relationship

		Semantically similar (*n* = 32)	Associated (*n* = 18)
Control group (*n* = 40)	Mean	.55 (.96)	.03 (.16)
	Range	0-4	0-1
PWA group (*n* = 20)	Mean	2.05 (1.67)	.25 (.72)
	Range	0-6	0-3

Note. Standard deviation in brackets.

The control group made fewer errors in all the distractor categories than the PWA group. Both groups made more semantic than phonological or unrelated errors. The effect of semantic stimuli relationship was considered; the majority of errors that occurred in the semantic category were semantically similar distractors rather than associated distractors.

8.3 Response latency: data preparation and descriptive statistics

8.3.1 Data preparation

For the reaction time data, errors were excluded from the analysis and the same data trimming methods were applied as in the WPV data preparation. Unlike the SP task, no exclusionary trimming was necessary: no premature responses were made and reaction times exceeding 10 seconds were not trimmed.

Each participant's raw data was viewed and descriptive statistics generated. In the by-participant analyses, each participant's response latency mean and standard deviation was computed and reaction times more than two standard deviations from the mean were replaced as appropriate with the mean plus or minus two standard deviations. At the by-item level where target items' response latencies deviated more than two standard deviations from the mean, the value was replaced with the mean plus or minus two standard deviations. The following descriptive statistics only includes accurate responses. Reaction times to targets will be presented, and data are split into the two conditions of whether a semantically similar or associated distractor was present in the array.

8.3.2 Descriptive statistics

The spread of individual participant response latency to targets in the WPM task is presented in Figure 8.2. Group reaction times to accurate target responses are presented in Table 8.4, including response latency to targets overall and when subcategorised into targets presented with distractors with a semantically similar or associated relationship to the target.

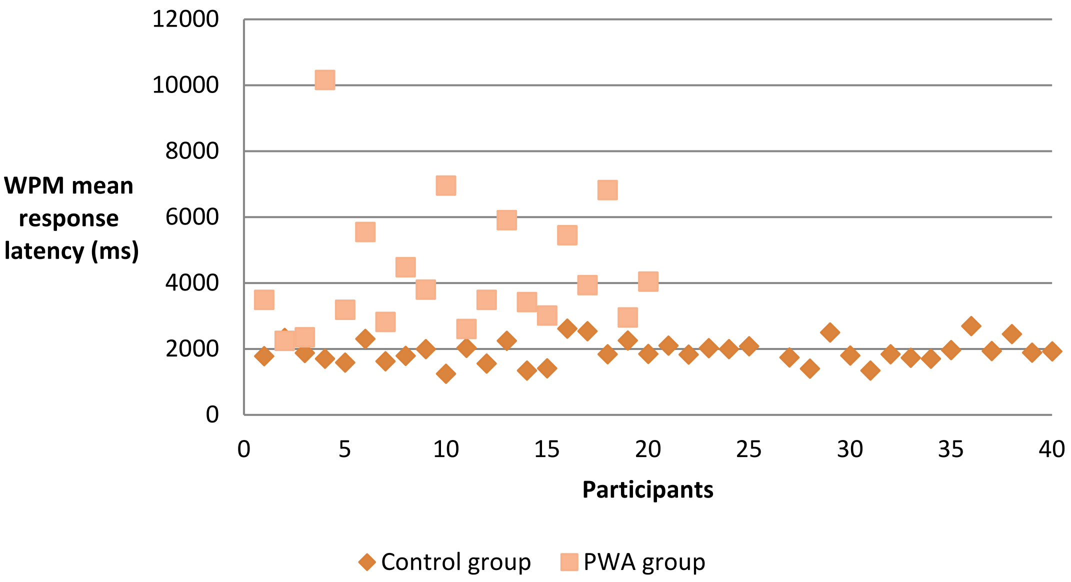

Figure 8.2: Individual participant mean response latency to targets in the WPM task

Table 8.4: Response latency to targets overall and by distractor relationship (ms)

		Overall response latency to targets (50)	Semantically similar condition (32)	Associated condition (18)
Control group (*n* = 40)	Mean	1934 (359)	1974 (362)	1861 (364)
	Range	1249-2696	1276-2731	1861-1201
PWA group (*n* = 20)	Mean	4339 (1967)	4345 (1810)	4331 (2329)
	Range	2248-10161	2390-9993	2005-10458

Note. Standard deviation in brackets.

On visually inspecting the data, the PWA group took more time to respond than the control group. Both groups showed a trend of taking longer to respond in the semantically similar distractor condition in comparison to the associated condition, with a larger difference visible for the control group.

8.4 Within-group comparisons of accuracy and error rates: planned analyses

Within each group, two areas were explored: i) the patterns of responses to stimuli, and ii) the effects of stimuli relationship (whether targets appeared with a semantically similar or associated distractor) on accuracy and response time to targets.

Firstly, the patterns of responding to targets and distractors within each group of participants were investigated. Participant responses to the four stimuli categories of target (correct), semantic, phonological and unrelated distractors were entered into Friedman tests (the non-parametric alternative to a one-way repeated measures ANOVA) to measure each group's responses to the different stimuli types[19]. Post-hoc repeated measures Wilcoxon Signed Rank Tests were applied to investigate response differences between categories; firstly treating the semantic distractors as one category, and then separating them into semantically similar and associated distractor categories. Only accurate responses to targets were included in response latency analysis, therefore no reaction time analyses are reported in this section as it explores error patterns.

Secondly, the effect of stimuli relationship condition (i.e. whether targets appeared in an array with either a semantically similar or associated distractor) on accuracy and response latency to targets, was investigated within each group of participants. In contrast to the first level of analysis which focused on error rates across categories, these analyses focus on comparison of the context of either a semantically similar or associated distractor. In all response latency analyses, only accurate responses were included. At the participant level repeated measures Wilcoxon tests were used for each group to compare the effect of stimuli relationship condition on i) accuracy and ii) response latencies. At the item level independent samples Mann-Whitney U tests were used for each group to compare the effect of stimuli relationship on i) accuracy and ii) response latencies. In these tests the targets under consideration were different within the semantically similar and associated categories. For accuracy analyses of semantically similar (*n* = 32) and associated (*n* = 18) items, raw scores were converted into proportions due to the different number of targets in each category.

8.4.1 Within-group accuracy and error rates: results

Results of within-group responses across the different stimuli categories are presented in Table 8.5. Medians are presented for the results of non-parametric testing; mean category response rates can be viewed in Table 8.2.

Table 8.5: Within-group analysis of WPM responses to stimuli categories

	Target median	**Semantic median**	**Phonological median**	**Unrelated median**	χ^2	***df***	***p***
Control group	50	0	0	0	106.36	3	.000***
PWA group	47.5	2	0	0	49.54	3	.000***

Note. χ^2 *= Friedman test statistic*; *df = degree of freedom; p* = significance.
****p* ≤ .001.

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[19] The no response error was not included in this analysis, as it was due to programme malfunction rather than participant error.

For the control group and PWA group there was a statistically significant difference in the number of responses in each category. Six post hoc investigations were subsequently applied for each group to identify the differences between the four categories. Bonferroni correction is applied (=.05/6) and significance values reported at .008 in Table 8.6.

Table 8.6: Post hoc comparisons of WPM responses to stimuli categories

	Control group (*n* = 40)			**PWA group (*n* = 20)**		
	z	*p*	*r*	*z*	*p*	*r*
Target vs semantic	-5.68	.000**	.90	-3.93	.000**	.88
Target vs phonological	-5.69	.000**	.90	-3.93	.000**	.88
Target vs unrelated	-5.69	.000**	.90	-3.94	.000**	.88
Semantic vs phonological	-3.09	.002*	.49	-3.32	.001**	.74
Semantic vs unrelated	-3.11	.002*	.49	-3.45	.001**	.77
Phonological vs unrelated	-.58	.564	-	-2.11	.035	-

Note. z = Wilcoxon Signed Rank test; *p* = significance; *r* = effect size.
**$p \leq .001$. *$p \leq .008$.

Both groups made significantly more accurate target responses than distractor stimuli responses, with large effect sizes for all comparisons. Both groups made significantly more semantic errors than phonological or unrelated errors, with medium effect sizes for control participants and large effect sizes for the PWA group (Cohen, 1988). There was no significant difference in number of error responses made between the phonological or unrelated distractors for either group.

8.4.1.1 Error rates of semantically similar versus associated stimuli

Error analyses were conducted to examine if there were differences in types of error responses made when the semantic category was separated into semantically similar distractors or associated distractors. The number of semantically similar and associated errors were compared to each other, and to the number of phonological and unrelated errors, using Wilcoxon Signed Rank Test pairwise comparisons. As discussed, proportion of responses made by participants, rather than the raw number of responses, were entered into the analysis. Bonferroni correction is applied (=.05/5) and significance values reported at .01.

Table 8.7 presents the median proportion scores for the distractor categories entered into semantically similar and associated post-hoc tests.

Table 8.8 presents the findings of the Wilcoxon Signed Rank test pairwise comparisons. Medians are presented for the purposes of non-parametric tests, however means can be viewed in Table 8.2 and Table 8.3.

Table 8.7: Median proportion of errors made to distractor stimuli

	Semantically similar (*n* = 32)	**Associated (*n* = 18)**	**Phonological**	**Unrelated**
Control group	0	0	0	0
PWA group	6.25	0	0	0

Table 8.8: Post-hoc comparisons of Word to Picture Matching error analysis

	Control group (*n* = 40)			**PWA group (*n* = 20)**		
	z	*p*	*r*	*z*	*p*	*r*
Semantic and associated	-3.15	.002*	.50	-3.53	.000**	.79
Semantic and phonological	-3.28	.001**	.52	-3.49	.000**	.78
Semantic and unrelated	-3.22	.001**	.51	-3.61	.000**	.81
Associated and phonological	.000	1.000	.	-.06	.952	.
Associated and unrelated	.45	.655	.	-1.23	.221	.

Note. z = Wilcoxon Signed Rank test; *p* = significance; *r* = effect size.
***p* ≤ .001. **p* ≤ .01.

The control and PWA groups both made significantly more semantically similar than associated errors, with large effect sizes (Cohen, 1988). Both groups made more semantically similar errors than phonological and unrelated errors, with large effect sizes for all comparisons. There was no significant difference in the number of associated, phonological or unrelated errors made for either group. It can therefore be concluded that the errors made in the semantic category were from arrays where targets appeared with a semantically similar distractor rather than an associated distractor.

8.4.2 Within-group effects of stimuli relationship

The effects of semantic distractor condition on accuracy and response latency are now examined. This includes consideration of two sets: targets presented in an array with a semantically similar distractor (*n*=32) and targets presented with an associated distractor (*n*=18). For completeness, analyses are completed at both the participant and item level. Only accurate responses only are included in the response latency analyses.

8.4.2.1 Effect of stimuli relationship: accuracy results

The group accuracy comparisons of stimuli relationship are presented in Table 8.9 for participant level analysis and Table 8.10 for item level analysis. Means and medians of proportion scores are presented for accuracy. Medians are reported in line with non-parametric test reporting.

Table 8.9: By-participant effect of stimuli relationship on group accuracy (proportion scores)

	Semantic distractor context						
	Semantically similar mean (32)	Associated mean (18)	Semantically similar median	Associated median	*z*	*p*	*r*
Control	.98 (.03)	.99 (.02)	1.00	1.00	-1.57	.137	-
PWA	.93 (.06)	.96 (.08)	.94	1.00	-2.31	.019*	.36

Note. Standard deviation in brackets. *z = Wilcoxon Signed Rank test*; *p* = significance; *r* = effect size.
**p* ≤ .05.

Table 8.10: By-item effect of stimuli relationship on group accuracy (proportion scores)

	Semantic distractor context						
	Semantically similar mean (32)	Associated mean (18)	Semantically similar median	Associated median	*U*	*z*	*p*
Control	.98 (.03)	.99 (.01)	1.00	1.00	248.5	-.99	.311
PWA	.93 (.08)	.96 (.06)	.95	1.00	203	-1.82	.070

Note. Standard deviation in brackets. *U* and *z* = Mann-Whitney U test statistics*;* *p* = significance.

At both the participant and item levels of analysis, the control group and PWA group were more accurate in the associated context; this reached significance for the PWA group at the participant level only, with a medium effect size.

8.4.2.2 Effect of stimuli relationship: response latency results

The effect of stimuli relationship on response latency are presented in Table 8.11 for the participant level of analysis and Table 8.12 for the item level. Mean and median scores are presented for response latency.

Table 8.11: By-participant effect of stimuli relationship on group response latency (ms)

	Semantic distractor context						
	Semantically similar mean (32)	Associated mean (18)	Semantically similar median	Associated median	*z*	*p*	*r*
Control	1974 (361.73)	1861 (363.87)	1921	1830	-4.79	.000***	.53
PWA	4345 (1809.80)	4331 (2328.86)	3823	3336	-1.31	.202	-

Note. Standard deviation in brackets. *z = Wilcoxon Signed Rank test*; *p* = significance; *r* = effect size.
****p* ≤ .001.

Table 8.12: By-item effect of stimuli relationship on group response latency (ms)

Semantic distractor context							
	Semantically similar mean (32)	Associated mean (18)	Semantically similar median	Associated median	*U*	*z*	*p*
Control	1987 (318.78)	1856 (263.62)	1933	1809	229	-1.19	.240
PWA	4344 (902.98)	4439 (1496.16)	4219	4067	273	-.30	.772

Note. Standard deviation in brackets. *U* and *z* = Mann-Whitney U test statistics; *p* = significance.

At the participant level, both groups demonstrated faster response latencies in the associated stimuli condition, however this only reached significance for the control group, with a large effect size. At the item level the control group presented with a faster response rate to targets in the associated condition, and the PWA showed a faster response rate to targets in the semantically similar condition; however these trends did not reach significance.

8.4.3 Summary of within-group response patterns and effect of stimuli relationship

Both groups made mainly accurate responses, selecting target images more than any distractor type. The error analysis demonstrated that significantly more semantic distractors were chosen than phonological or unrelated distractors, for both groups. When divided into their subcategories of semantically similar and associated distractors, significantly more semantically similar errors were made than associated errors, for both groups.

The effect of stimuli relationship was then examined at the participant and item levels of analysis to investigate if the semantically similar or associated distractor context affected response accuracy and response latency. At the participant and item levels of analysis both groups were more accurate in the associated distractor context, yet this was only significant for the PWA group at the participant level. A processing advantage for associated condition was also present for control participants in terms of quicker response latency, which reached significance at the participant level. The PWA group showed a small trend towards faster reaction times in the associated context at the participant level, and faster reaction times in the semantically similar context at the item level, yet both trends were non-significant.

8.5 Word to picture matching between-group comparisons

8.5.1 Planned analysis

Control group and PWA group accuracy and response latencies in the WPM task were compared at the participant and item levels of analysis. By-participant comparison of the two groups involved independent samples, therefore Mann-Whitney U tests were used to firstly compare group accuracy and response latency. By-item comparison of the two groups' overall accuracy and reaction time involved paired samples so was carried out using Wilcoxon Signed Rank test. Both groups completed the WPM task on one occasion only, seeing all items once, therefore raw accuracy scores were entered into the accuracy analyses.

8.5.2 Between-group accuracy and response latency comparisons

The control and PWA between-group comparisons for accuracy and response latency are presented below. See

Table 8.13 for the participant level and Table 8.14 for the item level results.

Table 8.13: By-participant control and PWA group comparisons

	Control mean (*n* = 50)	**PWA mean (*n* = 50)**	**Control median**	**PWA median**	***U***	***z***	***p***	***r***
Accuracy	49.32 (1.05)	46.95 (3.07)	50	48	134	-4.40	.000***	.57
Response latency	1934 (359)	4339 (1967)	1886	3648	17	-6.01	.000***	.78

Note. Standard deviation in brackets. *U* and *z* = Mann-Whitney U test statistics; *p* = significance level; *r* = effect size.
****p* ≤ .001.

Table 8.14: By-item control and PWA group comparisons

	Control mean (*n* = 40)	**PWA mean (*n* = 20)**	**Control median**	**PWA median**	***z***	***p***	***r***
Accuracy	39.46 (1.09)	18.78 (1.50)	40	19	-6.23	.000***	.62
Response latency	1940 (304)	4378 (1138)	1907	4112	-6.15	.000***	.62

Note. Standard deviation in brackets. *z* = Wilcoxon Signed Rank test statistic; *p* = significance level; *r* = effect size.
****p* ≤ .001.

At both the participant and item levels, the control participant group was significantly more accurate and faster in selecting the correct target than the PWA group, with large effect sizes for all comparisons (Cohen, 1988).

8.6 Descriptive statistics: individual PWA performance

Individual PWA accuracy and the control group mean accuracy are illustrated in Figure 8.3, and mean accurate response times to targets are shown in Figure 8.4. The full WPM results of individual PWA including accuracy, response latency and response patterns can be found in Appendix Q.

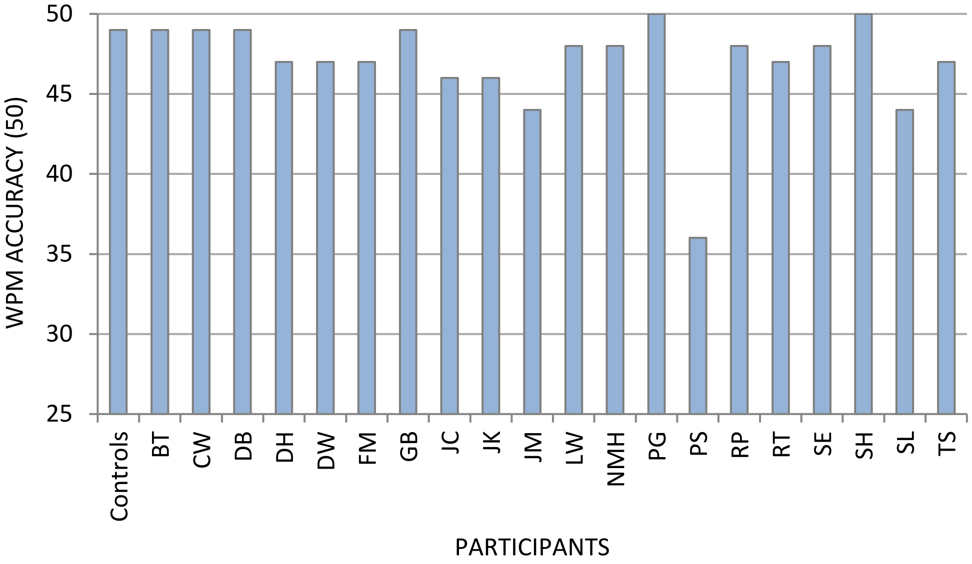

Figure 8.3: Control group mean and individual PWA WPM accuracy

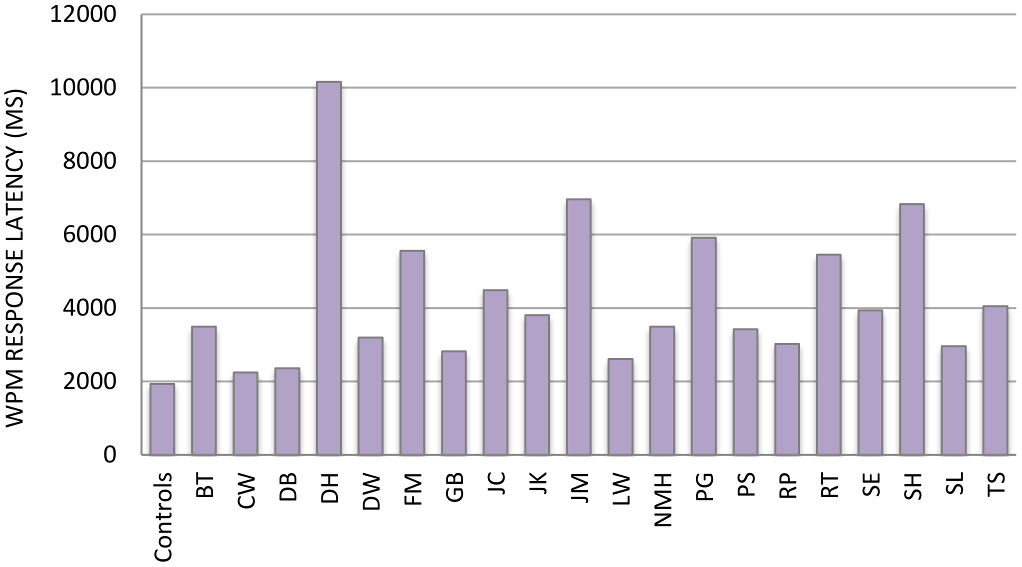

Figure 8.4: Control group mean and individual PWA mean WPM response latency

PG and SH made no errors and therefore performed more accurately than the control group mean. Four PWA (BT, CW, DB and GB) scored the same as the control group mean accuracy, with the remaining 14 PWA performing less accurately than the control group. All PWA performed significantly above chance (.25). When viewing error patterns across the three lowest scoring PWA, JM and SL made predominantly semantic errors, whereas PS made a range of errors across all distractor categories. All individual PWA demonstrated longer accurate mean reaction times compared to the control group. For both accuracy and response latency measures, individual PWA results are statistically compared to the control group in section 9.3.

8.7 Word to picture matching summary

In the WPM task both groups made more semantic errors than phonological or unrelated errors, and these tended to be semantically similar rather than associated distractor errors.

The effect of stimuli relationship condition was investigated within the two groups. At the participant and item levels there was a trend towards increased accuracy in the context of an associated distractor than a semantically similar distractor, which was significant only for PWA at the participant level of analysis. There were two main effects of stimuli relationship condition. Firstly, at the participant level the PWA group responded significantly more accurately to targets presented with an associated than a semantically similar distractor, an effect that was not present for the control group. Secondly, the control group showed faster response latencies to targets presented with an associated distractor than to those with a semantically similar distractor at the participant level, whereas there was no significant difference in response latency between stimuli contexts for the PWA group. Neither group demonstrated significant item level effects of stimuli relationship condition on accuracy or response time.

The between-group analysis demonstrated that the control group were significantly faster in responding to targets and significantly more accurate than the PWA group. At the individual PWA level, fourteen PWA responded less accurately than the control group in the WPM task, and all PWA were slower to make accurate responses to targets than the control group.

8.8 Summary of experimental task findings

The control group and PWA results of the experimental semantic tasks have been described in Chapters 6, 7 and 8. These are summarised before comparing performance across the three tasks.

In SP both the control group and PWA group demonstrated a significant priming effect at the participant level; this was not affected by whether the prime-target relationship was semantically similar or associated. For both groups, there was a trend towards a semantic priming effect at the item level, which was approaching significance.

These results were mirrored when the PWA SP time one data and control group SP data were compared at the participant and item level; the control group responded significantly faster than the PWA group overall, and both groups demonstrated a trend towards semantic priming that reached significance at the participant level only. The participant level priming effect was found to be of the same magnitude between groups.

At the PWA individual stage of analysis, four PWA demonstrated a significant semantic priming effect. Fifteen of the other 16 PWA demonstrated a trend towards a semantic priming effect that did not reach significance. Of the four PWA presenting with a semantic priming effect, this was of the same magnitude for semantically similar and associated prime-targets pairs. They also showed no significant difference in response latency between time one and two of testing, suggesting that the observed priming effects were of semantic/associative nature and not a result of repetition priming or task practice.

In the WPV task within-group comparisons, both groups of participants showed significantly faster and more accurate responses to targets in the congruent than incongruent condition, at both the participant and item levels of analysis. When considering performance in the incongruent condition, the control group were significantly more accurate in responding to associated distractor-target pairs than semantically similar pairs. However, no significant effect of target-distractor relationship was present for the PWA group. Target-distractor relationship did not affect response latency for either group.

In WPV between-group comparisons, at the participant level the control group were significantly more accurate than the PWA group in the congruent and incongruent conditions, for both semantically similar and associated distractor-target pairs. At the item level, no significant group differences in accuracy in the congruent condition were found, however the control group were significantly more accurate than the PWA group in the incongruent condition, again for both semantically similar and associated distractor-target pairs. The control group responded significantly faster than the PWA group across both conditions and both distractor types in the incongruent condition, at both the participant and item levels of analysis. The difference in response latency between congruent and incongruent conditions was greater for the PWA group than the control group. The difference in response latency to the different distractor relationships conditions was greater for the PWA group than the control group, with PWA performing faster in the associated condition.

Individual PWA were more accurate in the WPV congruent than incongruent condition, which reached significance for 15 individuals. Three PWA responded at chance level in the incongruent condition, potentially indicating a more severe semantic impairment. Accuracy in the incongruent condition was not significantly affected by the type of semantic distractor. Two PWA performed below chance in the semantically similar incongruent condition, while eight PWA performed below chance in the associated incongruent condition. These results should be treated with caution however, as there were fewer trials for associated pairs.

Individual PWA responded significantly faster to targets in the congruent than the incongruent WPV condition, apart from SE whose effect did not reach significance. There was no difference in response latency in the semantically similar and the associated distractor incongruent conditions for PWA, apart from SH who was significantly slower at responding to targets presented with associated distractors than semantic distractors.

In the WPM task, within-group error analyses showed that both PWA and control groups selected targets more than distractors. From the distractor error choices that were made, significantly more semantic distractors were selected than phonological or unrelated. Within the semantic category, the errors were found to arise from semantically similar distractors, which were selected significantly more than associative distractors.

The context of semantically similar versus associated distractor context within an array was investigated for effects on accuracy and response latency; at the participant level only the PWA group showed a significant effect for higher accuracy in the associated distractor condition. When response latency was considered, the control group responded significantly faster to targets in the associated condition, but this effect was not significant for the PWA group. No significant effects of semantically similar or associated distractor condition were present for either group at the item level of analyses.

When the PWA and control groups were directly compared on the WPM task, the control group was significantly more accurate and faster in accurate response than the PWA group at both the participant and item levels of analysis.

Overall, no significant differences were found between implicit semantic processing of the PWA and control group, as measured by SP effects in the implicit task, although the control group were significantly faster at making the explicit lexical decision than the PWA group. In contrast, the control group were significantly faster and demonstrated more accurate semantic processing on the explicit tasks, including the semantically incongruent condition of the WPV task, and overall on the WPM task.

When considering the effect of semantically similar versus associated stimuli, no significant effects were found in the SP task for either group, control participants showed some advantage for accuracy in the associated distractor condition in the WPV task, and in WPM both groups made more semantically similar than associated distractor errors. Further individual PWA analysis is presented in Chapter 9, including comparison of performance across tasks, investigation of the relationship between semantic task accuracy and response latency, and individual PWA within-task comparisons to the control group.

Chapter 9 Performance across the experimental semantic tasks

In Chapter 9 additional analyses are described which compare the results across the semantic tasks, and considers the PWA performance in greater detail. Four final stages of analysis are introduced below. Firstly, to compare performance across the implicit SP task and explicit WPV and WPM tasks, control and PWA within-group comparisons of performance between the three experimental semantic tasks were conducted, for both accuracy and response latency. Secondly, relationships between the three experimental semantic tasks were explored. Correlations of accuracy and response latency were run between the three semantic tasks for each group to investigate relationships between the tasks. Thirdly, individual PWA's accuracy and reaction time measures for each task were compared to the control group, to investigate patterns of performance within each PWA relative to controls. From these analyses two sub-groups of PWA emerged. Finally, in Chapter 10 the relationships between PWA scores on the experimental semantic tasks and other semantic and cognitive testing are explored, to investigate relationships between language and cognitive tests and the patterns of performance on the experimental semantic tasks.

9.1 Within-group performance between the experimental semantic tasks

9.1.1 Within-group between-task performance: planned analysis.

In the first stage of the analyses, non-parametric Friedman tests were carried out for each group to compare i) target accuracy overall and ii) target response latency between the semantic tasks. In SP related/unrelated conditions were combined and in WPV congruent/incongruent conditions were combined to provide the overall data. The analysis of task was repeated measures with three levels (SP, WPV, WPM). Raw scores were used as there were the same number of 50 targets in each task. For ease of comparison in this analysis SP accuracy to targets was used, i.e. lexical decision accuracy rather than SP effect, given the more direct comparability of these measures. The SP effect was used in subsequent correlational analyses as the SP task measure of semantic processing, which SP accuracy would not reveal. Post-hoc comparisons were subsequently conducted using related Wilcoxon Signed Rank Tests. Bonferroni correction is applied resulting in a significance level of .017 (=.05/3). Exact significance levels are reported. Effect sizes were computed for each comparison.

9.1.2 Within-group between-task performance: results

Table 9.1 displays group median accuracy and reaction times for each experimental semantic task, with post-hoc comparisons shown in

Table 9.2.

Table 9.1: Group median accuracy and response latency for semantic tasks

	Accuracy (50)			**Response latency (ms)**		
	SP	WPV	WPM	SP	WPV	WPM
Control group (*n* = 40)	50	47	50	951	1403	1887
PWA group (*n* =20)	49	44.5	47.5	1348	2456	3649

Note. SP = Semantic Priming; WPV = Word to Picture Verification; WPM = Word to Picture Matching.

Table 9.2: Semantic task pairwise comparisons of group accuracy

	SP vs WPV accuracy			**WPV vs WPM accuracy**			**WPM vs SP accuracy**		
	z	*p*	*r*	*z*	*p*	*r*	*z*	*p*	*r*
Control group (*n* = 40)	-5.37	.000***	.60	-4.98	.000***	.56	-0.75	.471	.
PWA group (*n* =20)	-3.74	.000***	.59	-3.93	.000***	.62	-1.23	.226	.

Note. SP = Semantic Priming; WPV = Word to Picture Verification; WPM = Word to Picture Matching. *z* = Wilcoxon Signed Rank test; *p* = significance; *r* = effect size.
***$p \leq .001$.

There was a significant difference in accuracy between tasks for the control group (χ^2 (2) = 52.31, $p < .001$), and PWA group (χ^2 (2) = 25.33, $p < .001$). Pairwise comparisons show that there was no difference in accuracy between the SP task and WPM task for either group. Both groups however were significantly less accurate at WPV than the SP and WPM tasks, with large effect sizes.

There was a significant difference in response latency between tasks for the control group (χ^2 (2) = 78.05, $p < .001$) and PWA group (χ^2 (2) = 40.00, $p < .001$). Pairwise comparisons are displayed in Table 9.3.

Table 9.3: Semantic task pairwise comparisons of group response latency

	SP and WPV response latency			**WPV and WPM response latency**			**WPM and SP response latency**		
	z	*p*	*r*	*z*	*p*	*r*	*z*	*p*	*r*
Control group (*n* = 40)	-5.51	.000***	.62	-5.47	.000***	.61	-5.51	.000***	.62
PWA group (*n* = 20)	-3.92	.000***	.62	-3.92	.000***	.62	-3.92	.000***	.62

Note. z = Wilcoxon Signed Rank test; *p* = significance; *r* = effect size.
***$p \leq .001$.

Post-hoc tests revealed significant differences in response latency for both groups with each pairwise comparison. The pattern was the same for both groups: the median response latency was lowest in the SP task (participants responded fastest to this task) and was greatest in the WPM task (participants responded slowest to this task), with WPV between the two. Large effect sizes were found for all comparisons in both groups. These analyses complete the first stage of between-task comparisons.

9.1.3 Within-group between-task comparison: summary

Within-group comparison has demonstrated that both control participants and PWA responded less accurately in the WPV task than in the SP and WPM task. No differences were found between accuracy in the SP and WPM tasks. Both groups followed the same pattern in their response latency to the semantic experimental tasks: participants responded most quickly to targets in the SP task, then the WPV task, and least quickly to targets in the WPM task.

It is important to note the different response windows in place in the experimental tasks for each participant group: control participants were given limited response times for each task, whereas PWA had unlimited time in which to respond. Control participants were given a response window of two seconds for the SP task, five seconds for the WPV task, and 10 seconds for the WPM task, therefore it is unsurprising that the median response latencies followed this incremental pattern. Interestingly however, this may be a true reflection of task processing time, as the PWA were unrestrained in response time and followed the same pattern.

9.2 Relationships between task accuracy and response latency

9.2.1 Correlation: planned analyses

In stage two of the between-task comparisons the relationship between accuracy and response latency to targets was investigated using Spearman’s rho correlations within each group. The non-parametric statistic Spearman’s rho was used due to the small sample sizes and the violations within the data of the assumptions of normality required for parametric tests; by ranking the data with these analyses the impact of outliers is reduced.

Relationships within and between tasks were examined. For the SP task the semantic priming effect was included as the accuracy measure of implicit semantic processing; the measure of lexical decision accuracy is not a semantic measure and therefore not of importance in these between task investigations. The SP response latency used in the reaction time analyses, which is time taken to make the lexical decision, but was included for completeness for response latency comparisons between tasks. Semantic Priming and WPV PWA analyses include data from time 1 and time 2 hence includes responses for accurate items in both the related and unrelated conditions.[20] Control participants only completed these tests on one occasion therefore all group data is included. For both groups, full WPM data is included for accurate responses. As comparisons were within-group, raw scores were used in all correlations.

Due to the number of multiple comparisons made (*n* = 5), for each group comparison, Bonferroni correction was applied to avoid Type 1 errors, resulting in an adjusted alpha level of significance (*p* = .01). All significance levels reported are two-tailed.

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[20] For completeness, analyses were conducted for the PWA group using SP and WPV time one response latencies only, however this did not alter the outcome.

9.2.2 Results of analyses

Table 9.4 displays the experimental semantic task accuracy and response latency correlations for the control group, and Table 9.5 presents the correlations for the PWA group.

Table 9.4: Control group correlations for experimental semantic task accuracy and response latency.

		SP effect	**WPV accuracy**	**WPM accuracy**	**SP response latency**	**WPV response latency**	**WPM response latency**
SP effect	Correlation coefficient	-	.066	.070	-.128	-.110	-.315
	Sig.		.684	.670	.432	.500	.048
WPV accuracy	Correlation coefficient		-	.171	.073	-.080	-.037
	Sig.			.291	.654	.626	.821
WPM accuracy	Correlation coefficient			-	.064	.248	.046
	Sig.				.695	.123	.780
SP response latency	Correlation coefficient				-	.442	.498
	Sig.					.004*	.001**
WPV response latency	Correlation coefficient					-	.653
	Sig.						.000**

Note. ***p* ≤ .001; **p* ≤ .01

Table 9.5: PWA group correlations for experimental semantic task accuracy and response latency

		SP effect	**WPV accuracy**	**WPM accuracy**	**SP response latency**	**WPV response latency**	**WPM response latency**
SP effect	Correlation coefficient	-	-.383	-.190	.353	.287	.305
	Sig.		.095	.422	.127	.220	.191
WPV accuracy	Correlation coefficient		-	.818	-.600	-.522	-.420
	Sig.			.000**	.005*	.018	.065
WPM accuracy	Correlation coefficient			-	-.463	-.249	-.181
	Sig.				.040	.289	.445
SP response latency	Correlation coefficient				-	.803	.800
	Sig.					.000**	.000**
WPV response latency	Correlation coefficient					-	.904
	Sig.						.000**

Note. ***p* ≤ .001; **p* ≤ .01.

9.2.2.1 Relationship in accuracy and response latency between tasks

There was no relationship in accuracy to targets between any of the three semantic experimental tasks for the control group, which is likely to be due to high performance across tasks. The PWA group demonstrated a significant positive relationship between WPV and WPM accuracy. There were significant positive relationships for response latency between all semantic tasks, for both groups.

No significant relationships between accuracy and response latency for semantic tasks were found for the control group. The PWA group demonstrated one significant negative relationship between SP response latency and WPV accuracy i.e. faster lexical decision reaction times were associated with greater WPV accuracy.

9.3 Individual PWA performance in comparison to the control group

9.3.1 Planned analysis: individual PWA performance

In the third stage of between-task analysis, individual PWA accuracy scores were compared to the control group values, within each semantic task. A measure for performance on each task compared to the control group was calculated; this is more valid than just observing the raw data, which would not provide an indication of how far outside norm it is. Analyses were conducted using the Singlims_ES.exe program available via J.R. Crawford's website[21] (Crawford, Garthwaite, & Porter, 2010). For each task, the control sample mean, standard deviation and sample size are entered into the analyses alongside the PWA score. For each task, a *t* test compared each PWA score to the mean of the control group to determine whether the PWA score was significantly different to the control group. This was then supported by an effect size and a point estimate of the atypicality of the PWA score i.e. the percentage of the population that would be expected to score lower than the PWA, with 95% confidence intervals. Crawford and Garthwaite (2002) propose that a point estimate of less than 2.5% would be rare in the population and would represent a large deficit in performance. Therefore, a point estimate that is equal to or larger than 97.5% may demonstrate a large advantage in performance (Burgoyne, Duff, Nielsen, Ulicheva, & Snowling, 2016). Two tailed significance levels are reported throughout. Observations of individual performance of across the three semantic tasks in comparison to the control group were then undertaken, to investigate if patterns in performance would result in subgroups of PWA based on their experimental semantic task profiles.

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[21] http://homepages.abdn.ac.uk/j.crawford/pages/dept/Single_Case_Effect_Sizes.htm

For the SP task, the SP effect for each individual was entered into the analyses, rather than accuracy scores, as the latter represents lexical decision accuracy rather than semantic processing function. For PWA time one and time two data from the SP task was entered into the analyses. For the WPV and WPM tasks total accuracy was used. For WPV this consisted of time one and time two data for PWA, and all control data, which were entered into the analyses as proportions. The WPM task was completed on one occasion by all participants therefore all data were included.

Response latency data were not included in the individual PWA analysis, as they do not represent measures of semantic processing so were not of primary interest at this point in the investigations.

9.3.2 Results: individual PWA performance

Results of the individual PWA analyses are presented in Table 9.6 for SP, Table 9.7 for WPV and Table 9.8 for WPM.

Table 9.6: Comparison of SP effect in the control group and individual PWA

Participant	Priming effect (ms)	*t*	*p*	Effect size	95% CI	Point estimate (95% CI)
Control group	16	-	-	-	-	-
BT	56	0.97	0.34	0.98	[0.60, 1.35]	83.05 [72.49, 91.21]
CW	26	0.24	0.81	0.25	[-0.07, 0.56]	59.50 [47.16, 71.16]
DB	3	-0.32	0.75	-0.32	[-0.63, 0.001]	37.74 [26.29, 50.05]
DH	182	4.02	<.001***	4.07	[3.11, 5.01]	99.99 [99.91, 100]
DW	15	-0.02	0.98	-0.02	[-0.33, 0.29]	49.04 [36.91, 61.24]
FM	63	1.16	0.25	1.18	[0.77 1.58]	87.37 [77.84, 94.25]
GB	110	2.28	0.03*	2.3	[1.70, 2.89]	98.57 [95.57, 99.81]
JC	32	0.39	0.70	0.39	[0.07, 0.71]	64.96 [52.70, 76.16]
JK	45	0.73	0.47	0.74	[0.38, 1.08]	76.39 [64.85, 86.02]
JM	126	2.66	0.01**	2.7	[2.02, 3.36]	99.44 [97.83, 99.96]
LW	96	1.91	0.06	1.94	[1.40, 2.46]	96.84 [91.96, 99.30]
NMH	-5	-0.51	0.61	-0.51	[-0.84, -0.18]	30.71 [20.00, 42.80]
PG	10	-0.15	0.89	-0.15	[-0.46, 0.17]	44.27 [32.36, 56.57]
PS	7	-0.22	0.83	-0.22	[-0.53, 0.10]	41.44 [29.71, 53.77]
RP	33	0.41	0.68	0.42	[0.09, 0.74]	65.85 [53.61, 76.95]
RT	30	0.34	0.74	0.34	[0.02, 0.66]	63.17 [50.87, 74.54]
SE	6	-0.22	0.83	-0.22	[-0.53, 0.10]	41.44 [29.71, 53.77]
SH	55	0.94	0.35	0.96	[0.58, 1.33]	82.44 [71.77, 90.76]
SL	55	0.97	0.34	0.98	[0.60, 1.35]	83.05 [72.49, 91.21]
TS	180	3.99	<.001***	4.04	[3.09, 4.98]	99.99 [99.90, 100]

Note. Effect size = difference between control group and PWA. CI = Confidence interval. Point estimate = percentage of a typical population expected to perform below the PWA's score.
***$p \leq .001$; **$p \leq .01$; *$p \leq .05$.

Four PWA (DH, GB, JM and TS) show a significantly greater semantic priming effect than the control group mean (*M* = 16ms), taking into consideration variance (*SD* = 40.82) and sample size (*n* = 40). These large semantic priming effects could be perceived as hyperpriming. No significance differences were found for the remaining 16 PWA.

Table 9.7: Comparison of WPV accuracy in the control group and individual PWA

Participant	WPV accuracy (proportion)	*t*	*p*	Effect size	95% Confidence interval	Point estimate (95% CI)
Control group	.93	-	-	-	-	-
BT	.95	0.66	0.51	0.67	[0.32, 1.01]	74.30 [62.55, 84.29]
CW	.93	0	1	0	[-0.31, 0.31]	50.00 [37.83, 62.17]
DB	.93	0	1	0	[-0.31, 0.31]	50.00 [37.83, 62.17]
DH	.80	-4.28	<.001***	-4.33	[-5.34, -3.32]	0.01 [0.00, 0.04]
DW	.91	-0.66	0.51	-0.67	[-1.01, -0.32]	25.70 [15.71, 37.45]
FM	.81	-3.95	<.001***	-4	[-4.93, -3.06]	0.02 [0.00, 0.11]
GB	.86	-2.31	0.03*	-2.33	[-2.93, -1.73]	1.33 [0.17, 4.21]
JC	.74	-6.26	<.001***	-6.33	[-7.76, -4.90]	0.00 [0.00, 0.00]
JK	.83	-3.29	<.001***	-3.33	[-4.13, -2.53]	0.11 [0.00, 0.57]
JM	.80	-4.28	<.001***	-4.33	[-5.34, -3.32]	0.01 [0.00, 0.04]
LW	.91	-0.66	0.51	-0.67	[-1.01, -0.32]	25.70 [15.71, 37.45]
NMH	.91	-0.66	0.51	-0.67	[-1.01, -0.32]	25.70 [15.71, 37.45]
PG	.97	1.32	0.20	1.33	[0.90, 1.76]	90.22 [81.62, 96.05]
PS	.72	-6.91	<.001***	-7	[-8.58, -5.42]	0.00 [0.00, 0.00]
RP	.91	-0.66	0.51	-0.67	[-1.01, -0.32]	25.70 [15.71, 37.45]
RT	.86	-2.31	0.03*	-2.33	[-2.93, -1.73]	1.33 [0.17, 4.21]
SE	.88	-1.65	0.11	-1.67	[-2.14, -1.18]	5.39 [1.60, 11.89]
SH	.90	-0.99	0.33	-1	[-1.38, -0.62]	16.47 [8.43, 26.93]
SL	.84	-2.96	0.01**	-3	[-3.73, -2.26]	0.26 [0.01, 1.18]
TS	.84	-2.96	0.01**	-3	[-3.73, -2.26]	0.26 [0.01, 1.18]

Note. Effect size = difference between control group and PWA. CI = Confidence interval. Point estimate = percentage of a typical population expected to perform below the PWA's score.
****p* ≤ .001; ***p* ≤ .01; **p* ≤ .05.

10 PWA (DH, FM, GB, JC, JK, JM, PS, RT, SL, TS) scored significantly lower than the control group mean proportion WPV accuracy (*M* =.93), taking into consideration control group variance (*SD* = 0.03) and sample size (*n* = 40). No significance differences were found for the other 10 PWA.

Table 9.8: Comparison of WPM accuracy in the control group and individual PWA

Participant	WPM accuracy	*t*	*p*	Effect size	95% Confidence interval	Point estimate (95% CI)
Control group	49	-	-	-	-	-
BT	49	-0.31	0.76	-0.31	[-0.630, 0.01]	37.89 [26.44, 50.21]
CW	49	-0.31	0.76	-0.31	[-0.630, 0.01]	37.89 [26.44, 50.21]
DB	49	-0.31	0.76	-0.31	[-0.630, 0.01]	37.89 [26.44, 50.21]
DH	47	-2.19	0.03*	-2.22	[-2.795, -1.63]	1.72 [0.26, 5.11]
DW	47	-2.19	0.03*	-2.22	[-2.795, -1.63]	1.72 [0.26, 5.11]
FM	47	-2.19	0.03*	-2.22	[-2.795, -1.63]	1.72 [0.26, 5.11]
GB	49	-0.31	0.76	-0.31	[-0.630, 0.01]	37.89 [26.44, 50.21]
JC	46	-3.13	.003**	-3.17	[-3.934, -2.40]	0.16 [0.00, 0.82]
JK	46	-3.13	.003**	-3.17	[-3.934, -2.40]	0.16 [0.00, 0.82]
JM	44	-5.01	<.001***	-5.08	[-6.237, -3.91]	0.00 [0.00, 0.00]
LW	48	-1.25	0.22	-1.27	[-1.680, -0.84]	10.92 [4.65, 19.92]
NMH	48	-1.25	0.22	-1.27	[-1.680, -0.84]	10.92 [4.65, 19.92]
PG	50	0.63	0.53	0.64	[0.294, 0.98]	73.39 [61.57, 83.53]
PS	36	-12.54	<.001***	-12.7	[-15.514, -9.87]	0.00 [0.00, 0.00]
RP	48	-1.25	0.22	-1.27	[-1.680, -0.84]	10.92 [4.65, 19.92]
RT	47	-2.19	0.03*	-2.22	[-2.795, -1.63]	1.72 [0.26, 5.11]
SE	48	-1.25	0.22	-1.27	[-1.680, -0.84]	10.92 [4.65, 19.92]
SH	50	0.63	0.53	0.64	[0.294, 0.98]	73.39 [61.57, 83.53]
SL	44	-5.01	<.001***	-5.08	[-6.237, -3.91]	0.00 [0.00, 0.00]
TS	47	-2.19	0.03*	-2.22	[-2.795, -1.63]	1.72 [0.26, 5.11]

Note. Effect size = difference between control group and PWA. CI = Confidence interval. Point estimate = percentage of a typical population expected to perform below the PWA's score.
****p* ≤ .001; ***p* ≤ .01; **p* ≤ .05.

Ten PWA (DH, DW, FM, JC, JK, JM, PS, RT, SL, TS) scored significantly lower than the control group mean WPM accuracy (*M* =49.33), taking into consideration control group variance (*SD* = 1.05) and sample size (*n* = 40). No significant differences were found for the remaining 10 PWA.

9.4 PWA subgroups

Individual PWA were subsequently categorised into subgroups who shared common performance across the three semantic tasks according to their individual comparisons to control group accuracy. Subgroup 1 consisted of PWA who were not significantly different in accuracy/SP effect to the control group across the three experimental semantic tasks (BT, CW, DB, LW, NMH, PG, RP, SE, SH). Subgroup 2 consisted of those who performed significantly less accurately than the control group on the two explicit semantic tasks WPV *and* WPM, and who on the implicit semantic priming task showed either a significantly greater semantic priming effect (*n*=3: DH, JM, TS), or an effect that was not significantly different to the control group (*n*=6: FM, JC, JK, PS, RT, SL). Two PWA (DW, GB) presented with individually mixed profiles and could not be categorised to either of these subgroups.

Table 9.9 presents a summary of subgroup 2 PWA performance in comparison to the control data, across each semantic task. Table 9.10 presents the results of the two PWA with profiles that did not fit into either of the two subgroups.

Table 9.9: PWA subgroup 2 semantic test profiles in comparison to the control group

Participant	**Semantic priming effect**	**WPV accuracy**	**WPM accuracy**
DH	***	***	*
FM	✓	***	*
JC	✓	***	**
JK	✓	***	**
JM	**	***	***
PS	✓	***	***
RT	✓	*	*
SL	✓	**	***
TS	***	**	*

Note. ✓ = No significant difference to control group variance; all other values are either a greater priming effect than controls (SP effect) or significantly less accurate (WPV and WPM accuracy). ***$p \leq .001$. **$p \leq .01$. *$p \leq .05$.

Table 9.10: PWA mixed semantic test profiles in comparison to the control group

Participant	**Semantic priming effect**	**WPV accuracy**	**WPM accuracy**
DW	✓	✓	*
GB	*	*	✓

Note. ✓ = No significant difference to control group variance; all other values are either a greater priming effect than controls (SP effect) or significantly less accurate (WPV and WPM accuracy). *$p \leq .05$.

The remaining two PWA showed opposite profiles to one another; DW was significantly less accurate than the control group on the WPM task only. GB however performed similarly to the controls on the WPM task, but was significantly less accurate than the control group on WPV, yet showed a greater priming effect in the semantic priming task. DW and GB will therefore not be considered further in the subgroup analysis. The control and the PWA group performance across the experimental semantic tasks are illustrated in Figure 9.1.

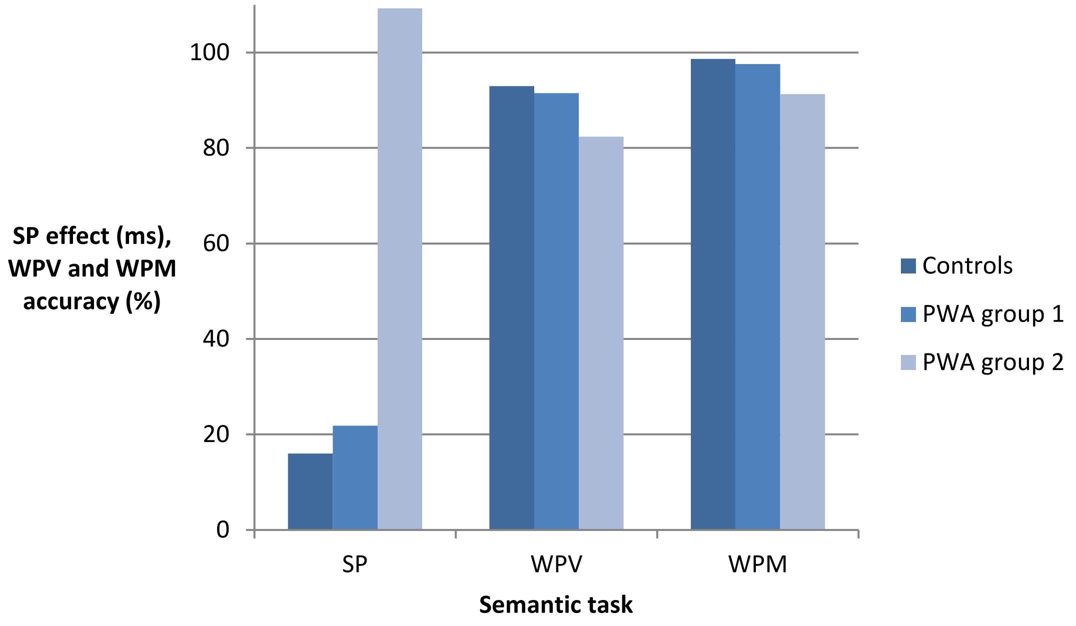

Figure 9.1: Semantic priming effect, WPV and WPM accuracy across participant subgroups

The PWA subgroup 1 performed similarly to the control group across the three semantic tasks. Subgroup 2, however show a different pattern; they perform significantly less accurately than the other groups on the two explicit semantic tasks of WPM and WPV, whereas on the implicit SP task they demonstrate greater priming, suggesting intact semantic processing. This pattern could be considered in light of hyperpriming claims, as previously discussed in relation to data from patients with Alzheimer's disease (Giffard, Desgranges, & Eustache, 2005; Nebes, Brady, & Huff, 1989). Within subgroup 2 are six PWA found to have both lexical semantic and non-verbal semantic impairment in the background assessment (FM, JC, JM, PS, SL, TS - see section 5.7.1.2), demonstrating impaired performance on tasks requiring explicit semantic decisions despite evidence of intact semantic knowledge on the implicit SP task.

9.4.1 Subgroup planned analyses

Following the categorisation of PWA into two main subgroups by accuracy scores across the semantic tasks, the performance of the subgroups and the control group were subsequently compared within each semantic task. Non-parametric independent samples Kruskal-Wallis Tests were used to analyse accuracy and response latency between the different groups.

In the accuracy analyses comparisons are made between subgroups and within tests, therefore different measures of accuracy were justified for each task. As in previous analyses, the semantic priming effect was used as the measure of SP task accuracy, with time one and time two data used to ascertain the priming effect. For the WPV PWA accuracy, time one and two data were used resulting in unequal numbers for comparison between control and PWA subgroups, therefore percentage correct are presented for all subgroups in this task. Raw scores were used for the WPM comparison, as all groups were exposed to the same 50 targets.

In the response latency analyses, SP reaction time is referred to. It is important to note that this is the time taken to make a lexical decision about all targets, in related and unrelated conditions, rather than a measure of semantic processing. However, for completeness this was included as a measure of task response latency for comparison to the other tasks.

9.4.2 PWA subgroup results: accuracy

Table 9.11 displays the Kruskal-Wallis Test results for the subgroup accuracy comparisons within the three semantic tasks. Due to small sample sizes Monte Carlo significance levels are reported.

Table 9.11: Between-subgroup comparison of accuracy

Accuracy	**Control group median** (*n* = 40)	**PWA subgroup 1 median** (*n* = 9)	**PWA subgroup 2 median** (*n* = 9)	**χ^2**	***df***	***p***
Semantic Priming effect (ms)	10.5 (40.76)	26.0 (32.45)	56.0 (65.99)	9.87	2	.005**
Word to Picture Verification accuracy (%)	94 (3.29)	91 (2.71)	81 (4.69)	23.16	2	.000***
Word to Picture Matching (raw score)	50 (1.05)	49 (.83)	46 (3.55)	25.60	2	.000***

Note. Standard deviation in brackets. χ^2 = Kruskal-Wallis Test Chi-Square value; *df* = degrees of freedom; *p* = significance level.
***p ≤ .001. **p ≤ .01.

For each semantic task there were significant differences in accuracy between each subgroup of participants. On the WPV and WPM tasks the control group performed more accurately than both the PWA subgroups. On the WPV and WPM tasks PWA subgroup 1 performed more accurately than the PWA subgroup 2. For semantic priming the reverse pattern was observed: the PWA subgroup 2 showed the largest semantic priming effect, while the control group showed the smallest priming effect.

To investigate differences between pairs of subgroups, post-hoc comparisons were conducted using Mann-Whitney U Tests. Bonferroni correction was applied resulting in a significance level of .017 (=.05/3). Effect sizes are reported in line with Cohen (1988). Comparisons made within each semantic task, for both accuracy and response latency included:

i) Control group versus PWA subgroup 1;

ii) Control group versus PWA subgroup 2;

iii) PWA subgroup 1 vs PWA subgroup 2.

Exact significance (2-tailed) is reported for pairwise comparisons, unless otherwise stated.

9.4.2.1 Pairwise comparisons: accuracy

Control group versus PWA subgroup 1 accuracy comparisons are presented in Table 9.12.

Table 9.12: Control group versus PWA subgroup 1 comparisons of task accuracy

	U	***z***	***p***
Semantic Priming	131.5	-1.25	.217
Word to Picture Verification	130	-1.31	.197
Word to Picture Matching	111.5	-1.96	.052

Note. U and *z* = Mann-Whitney U test statistics; *p* = significance.

Pairwise comparisons revealed that there were no significant differences in semantic task accuracy between the control group and the PWA subgroup 1. Control group versus PWA subgroup 2 accuracy comparisons are presented in Table 9.13.

Table 9.13: Control group versus PWA subgroup 2 comparisons of task accuracy

	U	***z***	***p***	***r***
Semantic Priming	64.5	-2.98	.002**	.43
Word to Picture Verification	4	-4.61	.000**	.66
Word to Picture Matching	9	-4.76	.000**	.68

Note. U and *z* = Mann-Whitney U test statistics; *p* = significance; *r* = effect size.
***p* ≤ .001.

The PWA subgroup 2 performed significantly less accurately on the explicit semantic measures of WPV and WPM, with large effect sizes. Conversely, they showed significantly greater SP effects than the control group, with a medium effect size. The two PWA subgroup comparisons of task accuracy are presented in Table 9.14.

Table 9.14: PWA subgroup 1 versus PWA subgroup 2 comparisons of task accuracy

	U	*z*	*p*	*r*
Semantic Priming	20	-1.81	.073	-
Word to Picture Verification	.000	-3.589	.000**	.85
Word to Picture Matching	.000	-3.63	.000**	.85

Note. U and *z* = Mann-Whitney U test statistics; *p* = significance; *r* = effect size.
$^{**}p \leq .001$.

The PWA subgroup 1 performed significantly better than the PWA subgroup 2 on the explicit semantic measures of WPV and WPM, with large effect sizes, however no significant difference was observed in SP effect.

9.4.2.2 Summary of accuracy pairwise comparisons

No significant differences in accuracy were found between the control group and PWA subgroup 1. Both of these groups demonstrated the same pattern of results in comparison to the PWA subgroup 2 in terms of explicit semantic tasks: they were significantly more accurate at WPV and WPM. However, the PWA subgroup 2 demonstrated significantly greater SP effects in the implicit task than the control group. There was a trend towards greater semantic priming for the PWA subgroup 2 compared to the PWA subgroup 1, however this did not reach significance.

9.4.3 PWA subgroup results: response latency

Table 9.15 presents the Kruskal-Wallis Test results for the subgroup response latency comparisons within the three semantic tasks. Due to small sample sizes Monte Carlo significance levels are reported.

Table 9.15: Between subgroup comparisons of response latency

	Control group median (*n* = 40)	**PWA subgroup 1 median** (*n* = 9)	**PWA subgroup 2 median** (*n* = 9)	χ^2	*df*	*p*
Semantic Priming	950.5 (110)	1139 (220)	1372 (316)	27.29	2	.000***
Word to Picture Verification	1403 (264)	3047 (1367)	4104 (2486)	37.01	2	.000***
Word to Picture Matching	1886.5 (359)	3491 (1594)	4485 (2232)	33.80	2	.000***

Note. Standard deviation in brackets. χ^2 = Kruskal-Wallis Test Chi-Square value; *df* = degrees of freedom; *p* = significance level.
$^{***}p \leq .001$. $^{**}p \leq .01$. $^{*}p \leq .05$.

Across all semantic tasks the same patterns in response latency were observed. The control group responded faster than both of the PWA subgroups, whereas the PWA subgroup 1 responded faster than the PWA subgroup 2. As significant subgroup differences were found within tasks, post-hoc pairwise comparisons were run using Mann-Whitney U tests. Bonferroni correction was applied resulting in a significance level of .017 (=.05/3).

9.4.3.1 Pairwise comparisons: response latency

Control group versus PWA subgroup 1 response latency comparisons are presented in Table 9.16.

Table 9.16: Control group versus PWA subgroup 1 comparisons of task response latency

	U	***z***	***p***	***r***
Semantic Priming	67.5	-2.91	.003*	.42
Word to Picture Verification	.000	-4.65	.000**	.66
Word to Picture Matching	17	-4.21	.000**	.60

Note. *U* and *z* = Mann-Whitney U test statistics; *p* = significance; *r* = effect size.
***p* ≤ .001. **p* ≤ .017.

The control group was significantly faster at making accurate responses in all of the experimental tasks than the PWA subgroup 1. Large effect sizes were found for the WPV and WPM task comparisons, and a medium effect size for the SP task (i.e. response latency to lexical decision). Control group versus PWA subgroup 2 response latency comparisons are presented in Table 9.17.

Table 9.17: Control group versus PWA subgroup 2 comparisons of task response latency

	U	***z***	***p***	***r***
Semantic Priming	.000	-4.65	.000**	.66
Word to Picture Verification	.000	-4.65	.000**	.66
Word to Picture Matching	.000	-4.65	.000**	.66

Note. *U* and *z* = Mann-Whitney U test statistics; *p* = significance; *r* = effect size.
***p* ≤ .001.

The control group was significantly faster at making accurate responses in all of the experimental tasks than the PWA subgroup 2, with large effect sizes for all comparisons. Table 9.18 displays the two PWA subgroup comparisons of response latency.

Table 9.18: PWA subgroup 1 versus PWA subgroup 2 comparisons of task response latency

	U	***z***	***p***	***r***
Semantic Priming	11	-2.61	.008*	.61
Word to Picture Verification	18	-1.99	.050	-
Word to Picture Matching	22	-1.63	.113	-

Note. *U* and *z* = Mann-Whitney U test statistics; *p* = significance; *r* = effect size.
**p* ≤ .017.

The PWA subgroup 1 was significantly faster at making a lexical decision in the SP task than the PWA subgroup 2, with a large effect size. Subgroup 1 was also faster than subgroup 2 at responding in the explicit tasks; this was approaching significance for the WPV subgroup.

9.4.4 Summary of response latency pairwise comparisons

The control group responded significantly faster than both PWA groups across all of the experimental semantic tasks. The PWA subgroup 1 responded faster than PWA subgroup 2 in all tasks; this only reached significance difference in the SP task comparison.

9.5 Individual PWA performance: summary

Two subgroups of participants with aphasia emerge from the comparison of individual PWA to the control group. Subgroup 1 (*n* = 9) includes PWA who showed no difference to the control group in any of the semantic three tasks in terms of SP effect and accuracy in WPV and in WPM. Subgroup 2 (*n* = 9) consists of PWA who showed no significant difference to the control group in terms of SP effect, or showed significantly greater SP effect than controls, and who were also significantly less accurate than the control group in WPV and WPM. Two PWA did not fit into these categories with a distinction between implicit and explicit semantic processing. DW performed similarly to the control group on SP and WPV, but less accurately in WPM. GB however performed similarly to controls on WPM, with greater priming effects in SP, but less accurately on WPV.

Within-task comparisons across these two groups showed that in terms of the semantic accuracy measures, PWA subgroup 1 did not differ significantly from the control group, and both of these groups performed significantly better on the two explicit WPV and WPM tasks compared to PWA subgroup2. The reverse pattern was apparent for the implicit SP task however, with the PWA subgroup 2 demonstrating more semantic priming than the other groups, which reached significance for the control group. This suggests that PWA subgroup 2 possess semantic knowledge that is not demonstrable on the explicit tests of semantic processing.

In terms of overall response latency, the control group responded significantly faster across all tasks. Subgroup 1 responded faster on all tasks than the PWA subgroup 2, however this only reached significance for the SP task.

Chapter 10 The relationship between experimental semantic tasks and participants' with aphasia performance on language and cognitive assessments

The final research questions sought to investigate the relationship between language and cognitive assessments, and performance on the experimental semantic tasks for the PWA group. In section 10.1, the relationships between performance on the experimental semantic tasks and performance on the clinical assessments of semantics are explored within the whole PWA group. Relationships between performance on the experimental semantic tasks and tests of memory, attention and executive function are then examined, for consideration of links between impaired cognitive control and access to and manipulation of semantic knowledge. In section 10.2 the same relationships between tests are re-examined in light of the subgroup distinction. Finally, in section 10.3, PWA subgroup performance on the semantic, cognitive and executive tasks is subsequently compared, in an attempt to differentiate the two subgroups by semantic and cognitive ability.

10.1 Semantic task and assessment comparisons - planned analyses

Semantic experimental task performance was compared to performance on a set of semantic assessments and a set of cognitive assessments. Published assessments included were selected to represent standard semantic tests used both clinically and in research, and a range of tests of memory, attention and executive function. Experimental semantic task accuracy (SP priming effect, WPM & WPV accuracy) and response latency were correlated with two groups of assessments, as detailed below. The same data used in the within experimental task correlations in section 9.2 were used; this included time one and time two data for SP and WPV tasks. All 20 PWA assessment results were included in the correlations.

i) Semantic assessments:

- Spoken and written word to picture matching test composite score (Comprehension Aphasia Test, CAT: Swinburn et al., 2004);
- Auditory synonym judgement (Psycholinguistic assessments of language processing in aphasia, PALPA: Kay et al., 1992);
- Written synonym judgement (PALPA: Kay et al., 1992);
- One non-verbal measure, the Pyramid and Palm Trees Test (Howard & Patterson, 1992).

ii) Cognitive and executive function measures:

- Elevator counting with and without distraction combined score (The Test of Everyday Attention, TEA: Robertson et al., 1994)
- Symbol Trails (Cognitive Linguistic Quick Test, CLQT: Helm-Estabrooks, 2001)
- Brixton spatial anticipation test (Burgess & Shallice, 1997)
- Raven's Matrices (Raven, 1956)
- Forwards digit span
- Towers of Hanoi – number of turns taken to complete the two disc level

For the semantic tasks two correlation matrices were generated; into the first of which the individual PWA language test scores, and scores for the SP effect, WPV accuracy and WPM accuracy were entered, and into the second of which the PWA language test scores and values for response latencies for SP, WPV and WPM were entered. Two further correlation matrices were generated in which the scores from the cognitive assessments were compared to the experimental semantic task accuracy and response latencies. For raw scores please refer back to Table 5.6 for cognitive tests and

Table 5.7 for language tests.

As the data were non-parametric, Spearman's rho correlations were used. Bonferroni correction was applied for the comparisons to avoid Type 1 errors. This resulted in adjusted alpha levels of significance for the four semantic comparisons (*p* = .013) and the six cognitive comparisons (*p* = .008). Two-tailed significance is reported throughout. The strength of relationships are reported in line with Cohen (1998).

10.1.1 Results: experimental semantic task and assessment correlations

Prior to the reporting of the relationship between semantic experimental tasks and semantic and cognitive tests, results of the correlations between the cognitive tests for the PWA group (*n* = 20) are presented in Table 10.1.

Table 10.1: Relationship between cognitive test accuracy for PWA

		Elevator counting	Symbol trails	Brixton	Raven's matrices	Digit span	Towers of Hanoi
Elevator counting	Correlation coefficient	-	.515	.396	.793**	.706**	-.556
	Sig.	-	.020	.084	.000	.001	.011
Symbol trails	Correlation coefficient		-	.146	.495	.573*	-.378
	Sig.		-	.538	.026	.008	.100
Brixton	Correlation coefficient			-	.477	.247	-.467
	Sig.			-	.034	.294	.038
Raven's matrices	Correlation coefficient				-	.541	-.671**
	Sig.				-	.014	.001
Digit span	Correlation coefficient					-	-.491
	Sig.					-	.028

Note. * *p* ≤.008. ** *p* ≤.001.

Significant relationships were present between the Elevator Counting composite accuracy score and Raven's matrices and the Digit span task; the Digit span task and Symbols trails; and the Towers of Hanoi and Raven's matrices. No other significant relationships were found, although some were approaching significance, including Elevator counting with and Symbol trails and Towers of Hanoi; Raven's matrices with Digit span and Symbol trails; and Towers of Hanoi with Digit span.

Table 10.2 displays the Spearman's rho correlations between the PWA group (*n* = 20) SP effect, WPV accuracy and WPM accuracy, and the group of semantic assessments.

Table 10.2: Relationship between experimental semantic task accuracy and semantic assessments for the PWA group

		WPM (CAT)	PPT	Auditory synonym judgement	Written synonym judgement
SP effect	Correlation coefficient	-.176	.068	-.503	-.267
	Sig.	.457	.776	.024	.256
WPV accuracy	Correlation coefficient	.523	.598*	.624*	.683**
	Sig.	.018	.005	.003	.001
WPM accuracy	Correlation coefficient	.544*	.760**	.510	.523
	Sig.	.013	.000	.022	.018

Note. * *p* ≤.013. ***p* ≤.001.

There was no significant relationship between SP effect and any of the other semantic measures. Large positive relationships were demonstrated between WPV accuracy and PPT, and both auditory and written synonym judgement; higher WPV accuracy is associated with higher scores on all three tests. The positive relationship between WPV with the CAT WPM did not reach significance with the adjusted alpha level.

Large positive relationships were present between the experimental WPM task and two semantic scores - the CAT WPM and the PPT; higher WPM accuracy was associated with higher CAT WPM and PPT accuracy. The WPM positive relationship with both synonym judgement tasks did not reach significance with the adjusted alpha level.

Spearman's rho correlations between the PWA group (*n* = 20) experimental task response latencies and the semantic assessments are presented in Table 10.3.

Table 10.3: Relationship between experimental semantic task response latencies and semantic assessments

		WPM (CAT)	PPT	Auditory synonym judgement	Written synonym judgement
SP response latency	Correlation coefficient	-.119	-.283	-.596*	-.313
	Sig.	.619	.227	.006	.179
WPV response latency	Correlation coefficient	.016	-.148	-.369	-.250
	Sig.	.947	.533	.110	.288
WPM response latency	Correlation coefficient	.172	-.151	-.385	-.228
	Sig.	.469	.525	.093	.334

Note. * *p* ≤.013. ***p* ≤.001

A significant relationship was found between SP response latency and one semantic test, auditory synonym judgement, with a large negative strength of relationship. Shorter SP response latencies were associated with higher auditory synonym judgement accuracy. There were no significant relationships between SP response latency and CAT WPM, PPT or written synonym judgement. No significant relationships were found between WPM or WPV response latency and any of the semantic tests. Correlation coefficients between the experimental semantic task accuracy and the assessments of cognition are presented in Table 10.4.

Table 10.4: Relationship between experimental semantic task accuracy and cognitive test accuracy

		Elevator counting	Symbol trails	Brixton	Raven's matrices	Digit span	Towers of Hanoi
SP effect	Correlation coefficient	.011	-.130	.013	.237	-.263	-.004
	Sig.	.965	.585	.956	.314	.262	.985
WPV accuracy	Correlation coefficient	.213	.427	.127	.342	.293	-.193
	Sig.	.368	.061	.595	.140	.210	.416
WPM accuracy	Correlation coefficient	.202	.396	.356	.467	.084	-.250
	Sig.	.392	.084	.124	.038	.725	.287

There was no significant relationship between the experimental task accuracy and any of the cognitive measures.

Table 10.5 displays the correlation coefficients between the experimental semantic task response latency and the assessments of cognition.

Table 10.5: Relationship between experimental semantic task response latencies and cognitive test accuracy

		Elevator counting	Symbol trails	Brixton	Raven's matrices	Digit span	Towers of Hanoi
SP response latency	Correlation coefficient	-.574*	-.669**	-.201	-.589*	-.571	.677**
	Sig.	.008	.001	.397	.006	.009	.001
WPV response latency	Correlation coefficient	-.367	-.496	-.019	-.282	-.356	.449
	Sig.	.111	.026	.937	.229	.124	.047
WPM response latency	Correlation coefficient	-.330	-.417	.048	-.276	-.388	.509
	Sig.	.155	.067	.840	.238	.091	.022

Note. * *p* ≤.008. ** *p* ≤.001.

Significant negative relationships were found between the SP response latency and three of the cognitive scores with a large strength of relationship for all, including the Elevator Counting composite, Symbols Trails and Raven's Matrices. Shorter SP response latencies were associated with greater test accuracy. The negative relationship between SP reaction time and digit span was approaching significance. A large positive relationship between SP response latency and the Towers of Hanoi number of turns to complete the two disc level was demonstrated, with shorter response latencies associated with fewer Hanoi turns (i.e. better performance).

No significant relationships were found between WPV or WPM response latency and the cognitive assessments. Those approaching significance include a negative relationship between WPV and Symbol Trails, and positive relationships between WPV and Towers of Hanoi, and WPM and Towers of Hanoi.

10.1.2 Summary: experimental semantic task and assessment correlations

In the semantic accuracy comparisons, SP accuracy, as measured by priming effect, was not related to any of the published semantic measures. Positive relationships were found between the WPM and WPV task and published semantic measures. Word to Picture Verification Accuracy was found to be significantly related to PPT, auditory and written synonym judgement accuracy, but not the CAT WPM composite accuracy. Word to Picture Matching accuracy was however significantly positively related to the CAT WPM composite accuracy and PPT accuracy, but did not reach significance for the two synonym judgement tasks.

In the semantic task response latency comparisons, a positive relationship was found between SP response latency (i.e. reaction time to lexical decision) and auditory synonym judgement. No significant relationships were present between SP response latency and CAT WPM, PPT or written synonym judgement. No significant relationships were demonstrated for WPM or WPV response latency and any of their published semantic tests comparisons. Thus suggesting that reaction time in semantic tasks is not a valid representation of semantic processing ability.

Across all semantic task accuracy and cognitive test comparisons, no significant relationships were found, suggesting that whole group level semantic processing (as measured by performance on the semantic tasks) was not related to performance on cognitive or executive function ability.

In the semantic task response latency and cognitive and executive test comparisons, significant relationships were found for SP response latency (i.e. reaction time to lexical decision) but not the WPV or WPM semantic tasks. Semantic Priming reaction time was significantly negatively related to three tasks, the Elevator Counting composite, Symbols Trails and Raven's Matrices, i.e. faster reactions times on SP were associated with greater accuracy in several cognitive tests. No significant relationships were reported between SP reaction time and Digit Span score, the Brixton or Towers of Hanoi task. For WPV and WPM, no significant relationships were found between response latency and any cognitive or executive function assessments. These results suggest that cognitive or executive function ability, as demonstrated by task accuracy, are not significantly related to the speed at which PWA complete semantic tasks.

The following section will continue to explore the same relationships between semantic experimental tasks and semantic and cognitive tasks, but using the aphasia subgroups identified in section 9.4, to investigate whether there are differences between the subgroups in terms of the relationships between tasks.

10.2 Subgroup correlations

In section 10.1 relationships between semantic task accuracy and response latency and performance on the semantic and cognitive assessments were explored for the PWA group as a whole. In this section of data analysis, to investigate if PWA subgroup differences were present, the comparisons are repeated, but for the two subgroups of PWA (9 in each subgroup). The same analyses were run – refer to section 10.1 for details of the methods used.

10.2.1 Results: subgroup semantic task and assessment correlations

The Spearman's rho correlations between the SP effect, WPV accuracy and WPM accuracy and semantic assessment performance are presented in Table 10.6 for PWA subgroup 1 and Table 10.7 for PWA subgroup 2. The adjusted alpha level of significance for the four semantic comparisons is applied (p = .013).

Table 10.6: Relationship between experimental semantic task accuracy and semantic assessments – PWA subgroup 1

		WPM (CAT)	PPT	Auditory synonym judgement	Written synonym judgement
SP effect	Correlation coefficient	.028	.560	-.235	.042
	Sig.	.944	.117	.542	.915
WPV accuracy	Correlation coefficient	.113	.531	.142	.688
	Sig.	.772	.141	.716	.040
WPM accuracy	Correlation coefficient	.266	.453	-.166	.300
	Sig.	.489	.220	.669	.433

Table 10.7: Relationship between experimental semantic task accuracy and semantic assessments – PWA subgroup 2

		WPM (CAT)	PPT	Auditory synonym judgement	Written synonym judgement
SP effect	Correlation coefficient	.167	.276	-.084	.101
	Sig.	.668	.472	.831	.796
WPV accuracy	Correlation coefficient	.301	.244	.519	.640
	Sig.	.431	.528	.152	.063
WPM accuracy	Correlation coefficient	.153	.582	.820*	.474
	Sig.	.695	.100	.007	.197

*Note.** *p* ≤.013.

For the PWA subgroup 1, no significant relationships were found between accuracy on the experimental semantic tasks and the semantic assessments. Only one significant relationship was found for the PWA subgroup 2, a large positive relationship between WPM accuracy and auditory synonym judgement accuracy which was not present in the whole group correlations.

Spearman’s rho correlations for SP, WPV and WPM response latency and semantic assessment accuracy are presented in Table 10.8 for subgroup 1 and Table 10.9 for subgroup 2.

Table 10.8: Relationship between experimental semantic task response latencies and semantic assessments – PWA subgroup 1

		WPM (CAT)	PPT	Auditory synonym judgement	Written synonym judgement
SP response latency	Correlation coefficient	.609	.446	-.782*	.042
	Sig.	.082	.229	.013	.915
WPV response latency	Correlation coefficient	.480	.192	-.521	-.192
	Sig.	.191	.620	.150	.620
WPM response latency	Correlation coefficient	.636	.157	-.807*	-.192
	Sig.	.065	.686	.009	.620

Note. * $p \leq .013$. ** $p \leq .001$.

Table 10.9: Relationship between experimental semantic task response latencies and semantic assessments – PWA subgroup 2

		WPM (CAT)	PPT	Auditory synonym judgement	Written synonym judgement
SP response latency	Correlation coefficient	.035	-.190	-.142	-.319
	Sig.	.928	.625	.715	.402
WPV response latency	Correlation coefficient	.018	.397	.209	-.008
	Sig.	.964	.290	.589	.983
WPM response latency	Correlation coefficient	.211	.293	.167	-.076
	Sig.	.586	.444	.667	.847

For PWA subgroup 1 only two significant, large, negative relationships were found between experimental semantic task reaction time and semantic assessment accuracy; higher scores on the auditory synonym judgement task were related to shorter response latencies on both the SP and WPM tasks. PWA subgroup 2 did not show any significant relationships.

Results of semantic task and cognitive assessment relationships are now considered by subgroup. Spearman's rho correlations between the SP effect, WPV accuracy and WPM accuracy and cognitive assessment performance are displayed in Table 10.10 for subgroup 1 and Table 10.11 for subgroup 2. The adjusted alpha level of significance for the six cognitive comparisons is applied (*p* = .008).

Table 10.10: Relationship between experimental semantic task accuracy and cognitive test accuracy - PWA subgroup 1

		Elevator counting	Symbol trails	Brixton	Raven's matrices	Digit span	Towers of Hanoi
SP effect	Correlation coefficient	-.183	-.160	.177	.521	-.252	-.079
	Sig.	.637	.681	.648	.150	.513	.839
WPV accuracy	Correlation coefficient	-.077	-.746	-.151	.013	-.258	.293
	Sig.	.845	.021	.698	.974	.503	.444
WPM accuracy	Correlation coefficient	-.347	-.525	.144	.045	-.755	.243
	Sig.	.360	.147	.711	.909	.019	.528

Table 10.11: Relationship between experimental semantic task accuracy and cognitive test accuracy - PWA subgroup 2

		Elevator counting	Symbol trails	Brixton	Raven's matrices	Digit span	Towers of Hanoi
SP effect	Correlation coefficient	.177	.094	-.437	.319	-.033	.103
	Sig.	.648	.810	.240	.402	.932	.793
WPV accuracy	Correlation coefficient	.489	.741	.182	.542	.613	-.194
	Sig.	.181	.022	.639	.131	.079	.617
WPM accuracy	Correlation coefficient	.676	.478	.288	.718	.474	.140
	Sig.	.046	.193	.453	.030	.197	.720

With the adjusted alpha level for multiple comparisons applied, no significant relationships were found between semantic task accuracy and cognitive test accuracy, for either subgroup.

Spearman's rho correlations between the SP, WPV and WPM response latency and cognitive assessment performance are displayed in Table 10.12 for PWA subgroup 1 and Table 10.13 for PWA subgroup 2.

Table 10.12: Relationship between experimental semantic task response latencies and cognitive test accuracy – PWA subgroup 1

		Elevator counting	Symbol trails	Brixton	Raven's matrices	Digit span	Towers of Hanoi
SP response latency	Correlation coefficient	-.817*	-.639	.270	-.605	-.555	.842*
	Sig.	.007	.064	.482	.084	.121	.004
WPV response latency	Correlation coefficient	-.450	-.251	.295	-.202	-.319	.436
	Sig.	.224	.515	.440	.603	.402	.241
WPM response latency	Correlation coefficient	-.750	-.434	.380	-.487	-.655	.574
	Sig.	.020	.244	.313	.183	.055	.106

Note. * p ≤.008. ** p ≤.001.

Table 10.13: Relationship between experimental semantic task response latencies and cognitive test accuracy – PWA subgroup 2

		Elevator counting	Symbol trails	Brixton	Raven's matrices	Digit span	Towers of Hanoi
SP response latency	Correlation coefficient	-.270	-.197	-.630	-.311	-.633	.684
	Sig.	.482	.612	.069	.415	.067	.042
WPV response latency	Correlation coefficient	.245	-.034	.017	.218	-.007	.436
	Sig.	.526	.930	.966	.572	.966	.241
WPM response latency	Correlation coefficient	.287	.043	-.008	.261	.033	.385
	Sig.	.454	.913	.983	.498	.932	.307

For subgroup 1 there were two significant large relationships found in the comparisons between semantic task response latency and cognitive test scores. A negative relationship was present between SP response latency and elevator counting, whereby shorter reaction times are associated with better scoring on the auditory attention task. A positive relationship was present between SP response latency and the Towers of Hanoi, i.e. longer SP reaction times were associated with a higher number of turns required to complete the two disc level. No other significant relationships were found for SP, or between WPV, WPM and any of the cognitive measures. For the PWA subgroup 2 no significant relationships were present between SP, WPV or WPM response latency or any cognitive tests.

10.2.2 Summary

When treated as smaller subgroups in correlation analyses, some of the whole group effects reported in section 10.1.1 were no longer present. In the whole group analysis relationships were found between WPV accuracy and performance on PPT and synonym judgement (PALPA) in both modalities, and also between WPM accuracy and both the word to picture matching (CAT) and PPT. In the subgroup analyses the only one of these relationships that was maintained included that between WPM and auditory synonym judgement, for PWA subgroup 2 only.

In the semantic reaction time analyses, at the whole group level there was only a significant negative relationship between Semantic Priming and auditory synonym judgement; this relationship was present for subgroup 2 only, whereas subgroup 1 showed a significant negative relationship between auditory synonym judgement and WPM response latency.

As with the whole group comparisons of semantic task accuracy and scores on cognitive tests, there were no relationships found for either PWA subgroup. In the whole group semantic task response latency comparisons with cognitive test scores, significant negative relationships were found between SP and four tests; Elevator Counting, Symbol Trails, Raven's Matrices and the Towers of Hanoi. In the subgroup analyses these relationships were not present for subgroup 2, whereas the two relationships remained for PWA subgroup 1; SP reaction time, Elevator Counting and Raven's Matrices, i.e. quicker lexical decisions were associated with higher scores on a test of auditory attention and a test of executive function.

10.3 Comparison of aphasia subgroups on semantic and cognitive tasks

In the final level of analyses, the two main subgroups of PWA were compared on their performance on standard language and cognitive measures, to investigate if subgroup language and cognitive profiles can account for their patterns of performance on the experimental tasks. Non-parametric Mann-Whitney U tests were used to investigate the differences between PWA subgroup 1 and PWA subgroup 2 performance across individual tests. Descriptive statistics and results of the Mann-Whitney U tests are presented for the language tests and then the cognitive tests.

10.3.1 Results of PWA subgroup comparisons on language tests

Subgroup descriptive statistics are summarised in Table 10.14. Mann-Whitney U comparisons between the performance of the two PWA subgroups are presented in Table 10.5. Refer to Table 5.6 and Table 5.7 for cognitive and language test raw scores.

Table 10.14: Descriptive statistics for PWA subgroup language test accuracy

	PWA subgroup 1			**PWA subgroup 2**		
Task	Mean	Range	Standard deviation	Mean	Range	Standard deviation
Minimal Pairs (40)	38.11	31-40	2.93	35.67	27-40	4.56
Auditory Lexical Decision (160)	143.78	126-158	11.53	133.67	105-159	19.34
Pyramids and Palm Trees (52)	50.11	48-52	1.17	46.22	38-50	4.18
Camel Cactus Test (64)	55.56	43-62	6.67	47.33	32-55	7.00
Spoken word to picture matching (CAT) (15)	14.89	14-15	.33	14.22	13-15	.97
Written word to picture matching (CAT) (15)	14.44	13-15	.88	13.67	11-15	1.32
Word to picture matching composite (CAT) (30)	29.33	28-30	.87	27.89	26-30	1.45
Category Comprehension Test (CSB) (64)	60.56	54-64	3.32	57.44	31-64	10.21
Auditory synonym judgement - high imageability (30)	28.00	22-30	2.60	25.11	19-28	3.10
Auditory synonym judgement - low imageability (30)	24.33	19-28	3.16	19.22	12-23	3.53
Written synonym judgement - high imageability (30)	28.78	28-30	0.83	27.33	24-29	1.73
Written synonym judgement - low imageability (30)	25.67	20-29	2.69	23.00	19-27	2.78

Note. Maximum score in brackets.

Table 10.15: Comparison of PWA subgroups performance on the semantic tests

Task	**Group 1 median**	**Group 2 median**	**Mann-Whitney U**	***z***	***p***
Minimal Pairs (40)	39	360	31	-.86	.402
Auditory Lexical Decision (160)	147	131	29	-1.02	.329
Pyramids and Palm Trees (52)	50	47	12	-2.60	.008**
Camel and Cactus Test (64)	57	49	15	-2.26	.023*
Spoken word to picture matching (CAT) (15)	15	15	25.5	-1.68	.135
Written word to picture matching (CAT) (15)	15	14	26	-1.39	.226
Word to picture matching composite (CAT) (30)	30	28	17	-2.18	.036*
Category Comprehension Test (CSB) (64)	62	61	35	-.49	.642
Auditory synonym judgement - high imageability (30)	29	25	14.5	-2.33	.018*
Auditory synonym judgement - low imageability (30)	25	20	10.5	-2.66	.006**
Written synonym judgement - high imageability (30)	29	28	20.5	-1.84	.077
Written synonym judgement - low imageability (30)	26	24	18.5	-1.97	.051*

Note. Maximum score in brackets. *U* and *z* = Mann-Whitney U test statistics; *p* = significance.

***p* ≤ .01. **p* ≤ .05.

Significant differences between subgroups were found on five semantic tests. Subgroup 1 scored significantly more accurately than subgroup 2 on the Pyramids and Palm Trees test, the Camel and Cactus Test, word to picture matching (CAT spoken and written scores combined), auditory synonym judgement (both high and low imageability items) and written synonym judgement; within the written version this difference was significant for low imageability items only. There were no significant differences in subgroup performance on auditory input tasks of minimal pairs and auditory lexical decision, the Category Comprehension Test (CSB), or word to picture matching (CAT) when the spoken and written modality versions were analysed separately.

10.3.2 Results of PWA subgroup comparisons on cognitive tests

Descriptive statistics for subgroup cognitive performance are displayed in Table 10.16, with Mann-Whitney U test subgroup comparisons reported in Table 10.17.

Table 10.16: Descriptive statistics for PWA subgroup cognitive test accuracy

	PWA subgroup 1			**PWA subgroup 2**		
Task	Mean score	Range	Standard deviation	Mean score	Range	Standard deviation
VOSP composite (50)	47.11	42-50	3.10	46.11	41-50	3.10
Symbol cancellation (12)	9.89	0-12	3.82	11.00	2-12	3.80
Elevator counting (7)	5.67	2-7	4.69	5.89	3-7	1.27
Elevator counting with distraction (10)	4.67	0-10	2.92	4.44	1-10	2.88
Digit span	3.38	2.3-5.1	1.01	2.97	1.5-4.7	1.12
Brixton raw accuracy	31.89	21-40	8.15	30.33	19-39	5.87
Symbol Trails test (10)	8.78	2-10	2.73	6.22	1-10	3.23
Towers of Hanoi (turns to 2 discs)	3.78	3-7	1.39	4.00	3-12	2.89
Raven’s Matrices (36)	29.67	18-36	5.64	26.22	16-35	6.74

Table 10.17: Comparison of PWA subgroup performance on the cognitive tests

Task	**Group 1 median**	**Group 2 median**	**Mann-Whitney U**	***z***	***p***
VOSP composite (50)	48	47	32.5	-.72	.505
Symbol cancellation (12)	11	11	39	-.14	.933
Elevator counting (7)	6	6	38.5	-.19	.901
Elevator counting with distraction (10)	5	4	36	-.40	.712
Digit span	3.5	3.1	28.5	-1.06	.306
Brixton raw accuracy	36	29	31.5	-.80	.448
Symbol Trails test (10)	10	6	21.5	-1.84	.070
Towers of Hanoi	3	4	26.5	-1.33	.216
Raven's Matrices (36)	31	25	26.5	-1.24	.229

Note. U and *z* = Mann-Whitney test statistics, *p* = significance level

Across the range of cognitive and executive function tests, there were no significant differences in subgroup performance.

10.3.3 Summary of results

The findings demonstrate that PWA subgroup 1 perform better on tests of semantics than subgroup 2, which is to be expected given that the group categorisation is based on performance on the explicit experimental semantic tasks of WPV and WPM. No subgroup differences were present for the auditory input tasks, or the range of cognitive tasks, selected to represent ability in visuospatial skills, auditory attention, short term memory, and executive functions such as planning, inhibition and flexible problem solving. This suggests that underlying cognitive and executive function skills do not account for the PWA subgroup performance observed on the experimental semantic tasks.

Chapter 11 Discussion

The overall aims of the current study were to investigate relationships between implicit and explicit semantic tasks in neurotypical control participants and PWA and to explore the impact of cognitive functions, including attention, memory and executive function, on task performance in PWA. Between-task comparison was achieved through development of three psycholinguistically matched lexical semantic experimental tasks; an implicit Semantic Priming (SP) task, and explicit Word to Picture Verification (WPV) and Word to Picture Matching (WPM) tasks. In these tasks consideration and matching was applied to assessment variables such as semantic similarity and association, and visual similarity between target and distractor words. Control participants provided normative data to compare to the PWA group and individual PWA performance. The performance of PWA on the experimental semantic tasks was subsequently compared to accuracy on standardised tests of lexical semantics, cognition and executive function. Key findings from Chapters 6, 7, 8, 9 and 10 will be discussed together in relation to the research questions, followed by consideration of the study's novel contributions, limitations, clinical implications and future directions.

The research questions of the project aimed to address a range of theoretical areas in the neurotypical control and PWA research literature. Firstly, the validity of explicit semantic testing and investigating the role of implicit testing of semantics in PWA; secondly, investigating whether the nature of semantic stimuli relationship influences task accuracy and response latency; and thirdly, whether PWA performance on semantic tasks is predicted by language or cognitive test scores, in the context of the relationship reported in the literature in relation to executive control of semantics. These three areas will be discussed in turn in sections 11.1, 11.2, and 0.

11.1 Theoretical implications: implicit and explicit task performance

The first research question examined the validity of explicit semantic tests in exploring PWA semantic function. It was hypothesised that explicit semantic tasks may be over-diagnosing semantic impairment in PWA. The current study is unique in its direct comparison of PWA performance on implicit and explicit semantic tasks that were controlled on a range of test variables to allow cross-task comparison. The rationale for this avenue of enquiry was to explore the idea that for PWA post-stroke, residual semantic knowledge which is not apparent via typical testing methods may be revealed via the implicit testing method of SP. This links to wider debate around the nature of semantic impairment in aphasia. Psycholinguistic models of single word processing, broadly speaking, account for semantic aphasic deficits in relation to impairment of access to semantics or degradation of stored semantic representations (Patterson & Shewell, 1987; Whitworth et al., 2014), whereas recent definitions of a hub and spoke architecture of semantic memory and the concept of impaired executive control of semantics in aphasia, have been proposed to account for the observed difficulties (Jefferies & Lambon Ralph, 2006). The proposal that the anterior temporal lobes provide an amodal store of semantic knowledge, which is connected to a distributed neural network of language, sensory and motor areas (Jefferies, 2013), is supported by findings of a relationship between the cognitive and language abilities of PWA (Kalbe et al., 2005) and cognitive ability and response to language therapy (Baldo et al., 2005; Fillingham et al., 2005a, 2005b, 2006; Hinckley & Carr, 2001; Lambon Ralph et al., 2010; Seniów et al., 2009). In the current study, implicit and explicit tasks were therefore used in an attempt to contribute to this area, by unpacking potential performance factors masking residual semantic processing. Several studies have examined the semantic processing of PWA in SP (Blumstein et al., 1982; Bushell, 1996; Milberg & Blumstein, 1981; Hagoort, 1989; Ostrin & Tyler, 1993; Prather et al, 1997; Tyler et al., 1995a, 1995b) and tasks such as WPV (Breese & Hillis, 2004; Howard & Gatehouse, 2006; Howard & Orchard-Lisle, 1984) and WPM, but no previous study has compared these tasks in the same participants.

The present study provides evidence of residual processing in PWA who would otherwise be described as having lexical semantic impairment. This is similar to the retained processing of syntax found in individuals with aphasia via implicit testing methods, when syntactic knowledge was not demonstrated on explicit tasks (Badecker, et al., 1995; Scarnà & Ellis 2002, Varley et al., 2005). Areas of evidence from within cognitive neuroscience, such as speeded or more accurate responses in priming tasks in patients with amnesia (Jacoby & Witherspoon, 1982; Cermak, Talbot, Chandler & Wolbarst, 1985), also suggest a dissociation between implicit and explicit recall knowledge (see Shimamura, 1986 for a review). With regard to semantic processing, the paradigm of semantic priming has been employed to investigate semantic processing in groups with impaired semantic knowledge. For example, children with specific language impairment (Nation & Snowling, 1999), people with semantic dementia (Moss et al., 1998; Nakamura et al., 2000); Alzheimer’s disease (Balota et al., 1999; Chertow & Bub, 1989, 1990); and aphasia (for a review see Del Toro, 2000). In all of these groups, SP effects have been taken to indicate intact semantic knowledge in the absence of its demonstration on explicit tasks, and further investigation of this in PWA was warranted.

11.1.1 Within-group performance on experimental semantic tasks

Before comparisons could be drawn regarding participant between-task performance, within group functioning on the three tasks was investigated, starting with findings from the implicit SP task. The first step taken was to explore whether the control group and PWA group demonstrated a semantic priming effect with the current SP methodology. Previously, SP studies with PWA have focused on the different patterns of semantic priming in Broca's and Wernicke's aphasia (Blumstein et al., 1982; Baum, 1997; Bushell, 1996; Del Toro, 2000; Hagoort, 1989, 1997; Holderbaum et al., 2016; Milberg & Blumstein, 1981; Milberg et al., 1987; Prather et al., 1992, 1997; Ostrin & Tyler, 1993; Stern et al., 1991; Tyler et al., 1995a; 1995b). This has resulted in a range of hypotheses regarding SP in PWA, including: i) intact automatic lexical semantic processing in people with Broca's and Wernicke's aphasia (Bushell, 1996; Hagoort, 1993, 1997; Ostrin & Tyler, 1993; Tyler et al, 1995a); ii) impaired automatic lexical semantic activation in both Broca's aphasia (delayed activation) and Wernicke's aphasia (delayed deactivation) (Prather et al., 1997; Yee, 2015); iii) reduced levels of lexical semantic activation in Broca's aphasia (Milberg & Blumstein, 1981), but typical or increased levels of semantic activation in Wernicke's aphasia in contrast to poor performance on explicit semantic assessment (Baum, 1997; Blumstein et al., 1982; Milberg et al., 1987; Yee, 2005). To our knowledge there are no large group studies of SP in PWA analysing individual effects in each participant, which the current study contributes. The PWA sample within the current study was not recruited according to syndrome classification of Broca's versus Wernicke's aphasia; the language and cognitive profiling undertaken allows comparison of SP effects with overall lexical semantic and cognitive processing (see sections 0 & 11.3.2 for discussions), which would be central to any differentiation in aphasia syndrome subgroups undertaken.

A range of heterogeneous methods and designs has been employed in SP experiments with PWA. These include: variation in modality of testing; methodological choices which influence the potential impact of strategic decision-making, such as use of paired versus continuous list presentation, variation in relatedness proportion within the task, and variation in ISI; and variation in control (or lack thereof) for the types of semantic or associative relationship between prime-target pairs (Carter et al., 2011). The heterogeneity in methodology has resulted in divergent and inconclusive findings of SP in PWA. Within the current study, methodological decisions were made to minimise the potential involvement of strategic processing in SP (McNamara, 2005), including the use of 0ms ISI (Perea & Rosa, 2002), low relatedness proportion (Neely, 1989) and a continuous list paradigm in the written modality (Moss et al, 1995; Shelton & Martin, 1992; de Mornay Davis, 1998), as Del Toro's (2000) review found more consistent priming in written list presentation of SP. Typically in SP studies, participants only see targets in one condition due to the potential impact of repetition priming contaminating the SP results. The design here involved a large group of PWA completing both related and unrelated conditions for all items, over two times of testing. This permitted in-depth analysis of priming in each individual (see section 11.1.2 for a discussion) and is the first study known to have used this design.

The control group and PWA group both showed the same pattern of SP results: SP effects were present at the by-participant level of analysis, and at the by-item level a trend towards faster responses in the related condition did not reach significance. The control findings are in line with the SP literature with neurologically intact participants, in which group level data provides evidence of robust semantic priming effects, as an average of individual performance (Meyer & Schvaneveldt, 1971; Neely, 1991; Yap, Hutchinson & Tan, in press). The lack of significant findings at the item level of analysis may be caused by the difference in power due to participant versus item sample size, as more items contribute to the participant analysis mean than the item analysis mean. In addition, some item variance may exist despite psycholinguistic matching of items. Of particular interest in the outcomes of this task was that the PWA group demonstrated SP to the same magnitude as the control group, thus demonstrating intact semantic processing.

In comparison to results from the implicit task, explicit task results are considered. There is a lack of previous research into the use of WPV as a measure of semantic processing, in neurologically unimpaired participants or PWA (studies which make use of a WPV task with PWA include Breese & Hillis, 2004; Howard & Franklin, 1988; Howard & Gatehouse, 2006; Howard & Orchard-Lisle, 1984; Morris & Franklin, 2012; Rapp & Caramazza, 2002) and no published versions exist. In contrast, WPM is a commonly used task to identify semantic deficits in PWA in both research and clinical settings (Bate et al., 2010; Cole-Virtue & Nickels, 2004b). The current study is unique in its detailed investigation of psycholinguistically matched WPV and WPM tasks in PWA at the group and individual level, and in terms of effects of semantically similar versus associated distractors (to be discussed in section 11.2). As expected, both control participants and PWA made more errors and were slower in the incongruent WPV condition. This is unsurprising, as the incongruent condition contains semantically similar or associated written distractors with target images, whereas the congruent condition contains only the target word and corresponding target image, hence there is no conflict to resolve or competition between related concepts. In both the WPV and WPM tasks, the control group performed significantly faster and more accurately to targets than the PWA group. Patterns of slowed responses in comparison to unimpaired control participants is often reported in PWA, and has been proposed to be related to a variety of factors, including neurological damage, effects of age, and depression (Nickels & Cole-Virtue, 2004). In published WPM assessments, a pattern of impaired aphasic performance is also predicted in comparison to unimpaired control groups (Swinburn et al., 2004; Kay el al., 1992). In summary, in contrast to the implicit SP task, the PWA group performed less accurately than the control group on both explicit semantic tasks. However, as individual PWA performance was explored, different subgroups of performance emerged; suggesting that some PWA who would have been identified as semantically impaired on the explicit measures, demonstrated retained semantic functioning on the implicit SP task.

11.1.2 Individual PWA performance and the emergence of subgroups

Individual PWA SP effects, and WPV and WPM task accuracy were each statistically compared to the control group performance using a method to identify differences between single participants and control groups, and which generates a point estimate scores of atypicality of individual performance (Crawford et al., 2010). Two main subgroups emerged, with two individual outliers. The first subgroup consisted of nine PWA who did not differ significantly to the control group on any of the three experimental semantic measures. The second subgroup of nine PWA performed less accurately than controls on the two explicit experimental tasks of semantic processing. On the implicit SP task however, subgroup 2 demonstrated intact semantic processing; six individuals did not perform significantly differently to the control group while the other three individuals showed a greater priming effect in comparison i.e. hyperpriming. Within subgroup 2 were six PWA who in the background testing demonstrated impaired lexical and non-verbal semantic processing, and two PWA with deficits in nonverbal semantic processing. The pattern of performance in the nine PWA in subgroup 2 is of particular interest, as it demonstrates semantic impairment on explicit tests of WPV and WPM, yet semantic knowledge is revealed when assessed implicitly via SP. This suggests that participants in the second group have better semantic potential than explicit tasks allow them to display, and therefore explicit tasks may not accurately represent residual semantic knowledge in all PWA.

These results are not in line with one explanation of semantic deficit in PWA, which is the proposal of degraded or lost semantic representations (Ellis & Young, 1996; Patterson & Shewell, 1987; Whitworth et al, 2014); damaged semantic knowledge would preclude semantic priming. Alternative theories of semantic processing such as the hub and spoke model (see Lambon Ralph et al, 2017 for a review), suggest that semantic representations are not damaged in aphasia. There is evidence that people with semantic aphasia instead lack the ability to access and manipulate their semantic knowledge flexibly via executive control mechanisms (Jefferies & Lambon Ralph, 2006), therefore due to the control elements of explicit tasks their potential is masked. Another factor that may contribute to impaired performance on explicit tasks is the test characteristic of two or more competing stimuli being present. It is possible that PWA are able to activate semantic representations, but once activated they cannot inhibit the related distractor item, either due to impaired semantic control mechanisms (Corbett et al., 2009; Noonan et al., 2010), or semantic refractory effects that occur in comprehension tasks due to repeated exposure to semantically related sets, causing impaired semantic access for a short period of time (Gardner et al., 2012; this is further discussed in section 11.1.3). The speed of the task can also be considered. It is possible that the 0ms ISI was too cognitively demanding for some PWA, and/or that by providing unlimited time for responses, additional strategic processing was applied, such as expectancy generation (Becker, 1980), or semantic matching (Neely, 1976, 1977). As all tasks were completed in the written modality, it is also possible that individual PWA could experience a particular difficulty accessing semantics from the orthographic input lexicon (Ellis, 1993; Whitworth et al, 2014), however, apart from DW's language processing at sentence level, a clear dissociation between spoken and written modalities was not found for any PWA within the background language testing.

The pattern of performance in subgroup 2 is important in response to the first research question, as it suggests that participants' semantic processing ability may be misunderstood from the results of commonly used explicit tasks, potentially resulting in misinformed clinical diagnosis, and subsequent misallocation of treatment. In line with clinical implications, discussed in section 11.5, the time and resources of both PWA and Speech and Language Therapy (SLT) services are expended inappropriately if semantic therapy is delivered to individuals with intact semantic processing, and the profitless activities could therefore lead to no improvement in lexical processing outcomes in PWA.

11.1.2.1 Hyperpriming in PWA

The hyperpriming demonstrated by three PWA in subgroup 2 will be considered in light of a range of explanations provided to account for hyperpriming in people with Alzheimer's disease (AD) (Giffard, Desgranges, & Eustache, 2005). As discussed in section 2.5.2, earlier studies in the field, such as Nebes, Brady, and Huff (1989), explain hyperpriming via generalised slowing of all responses in comparison to control participants. If PWA take much longer to respond in an unrelated condition, exposure to the targets in the related condition may result in a larger reduction in response latency. This results in a larger difference than that shown by control participants, who respond more quickly than PWA in the unrelated condition. The explanation of generalised slowing of responses could be applied to two of the participants demonstrating hyperpriming; JM and DH showed long response latencies in both related and unrelated conditions in comparison to other PWA and the control group, but does not account for the hyperpriming demonstrated by TS and GB. Conversely, other PWA with generalised slowed responses did not show hyperpriming, therefore a clear cut relationship between the two was not found in the current data.

Impaired attentional strategies have also been proposed to account for hyperpriming, with the suggestion that an attentional deficit increases the time taken to identify unrelated pairs of stimuli. This explanation developed from SP paradigms encouraging strategic processing, such as long SOAs or a high relatedness proportion of prime-target pairs (see Ober & Shenaut, 1995, for a review), and has not been upheld by studies employing methodologies designed to encourage automatic processing of stimuli (Giffard et al., 2001, 2002), as in the current study. However, in terms of overall response latency, PWA subgroup 2 responded significantly more slowly on the SP task than the subgroup 1, which could be indicative of participants employing more conscious, strategic processing strategies.

A further explanation suggests that hyperpriming is due to degraded stored semantic knowledge, as reflected on explicit tasks (Chertkow et al., 1989, 1994). Giffard et al. (2001, 2002) explain the hyperpriming phenomenon in AD as resulting from the early loss of featural semantic information, whilst superordinate information is preserved. It is proposed that this results in similarity between concepts and thus effects of repetition, that are known to result in more robust priming effects than semantic priming (Martin, 1992). For example, in the early stages of AD semantic coordinates (e.g. tiger versus lion) lose their distinguishing features (e.g. specific knowledge about stripes and a mane is lost) yet still possess overlapping features (e.g. shared habitat, being fierce) and are therefore processed as synonyms (i.e. fierce, wild animal). A reduction in priming effect is then observed over time as the knowledge degrades further and concepts share less similarity in the semantic store (Giffard et al., 2001, 2002). This idea of loss of featural information could be applied to the PWA within the current study, which would insinuate impaired flow of activation between related concepts, and result in poor performance on the explicit tasks. If tested again in a longitudinal study, it would be hypothesised that unlike the participants with AD, the hyperpriming effect present in the PWA would remain, as the PWA semantic knowledge would be presumed to be stable and not deteriorating as in AD. This has not been tested in the SP literature because, as discussed, the SP task is not typically repeated with the same individuals. However current knowledge of retesting PWA on explicit tasks demonstrates inconsistency between testing times (Caplan et al., 2007), or when the same items are retested in different tasks (Jefferies & Lambon Ralph, 2006), rather than degradation, supporting arguments for intact semantic knowledge but impaired semantic access or control mechanisms in PWA. In conclusion, there is not one explanation that can account for all hyperpriming responses observed in the PWA, however generalised slowing of responses account for the patterns demonstrated by JM and DH.

11.1.2.2 PWA subgroup outliers

In addition to the subgroups, two PWA presented with mixed profiles. DW performed typically on the SP and WPV tasks but made significantly more errors than the control group on the WPM task. DW only made one semantic error (*mouse-hamster*) but two phonological errors (*rocket-racket; napkin-pumpkin*). On the CAT written WPM test he also made one semantic error and one phonological error, however showed good semantic processing within the testing otherwise. Written sentence comprehension was also markedly impaired on the CAT, whereas spoken sentence comprehension was within typical limits, providing further evidence for a selective difficulty accessing meaning through the written modality, perhaps when task demands are higher or more stimuli are present, as semantic processing was intact on SP, WPV and written synonym judgement tasks. Difficulty accessing semantic knowledge in the presence of higher task demands would be consistent with his impaired executive functioning ability; he scored outside normal limits on Raven's Matrices, but also made the most errors out of the PWA group on the Brixton Spatial Anticipation test.

GB however was within normal limits on the WPM task, but significant differences to the control group were found on the SP and WPV tasks. He demonstrated a greater SP effect than controls, but poorer performance than controls on the WPV task. A WPV score of 36/50 and point estimate of 1.33 suggest significant impairment and is in great contrast to the hyperpriming shown via the implicit SP task. It is more challenging to provide explanation for this pattern in terms of executive control of semantics, as GB was one of four PWA who was within normal limits on all cognitive and executive function tests. On semantic tests he showed impaired lexical semantics on auditory synonym judgement and comprehension deficit at the sentence level in both modalities. It is important to note in his case that impaired performance on the WPV task is not consistent with the priming demonstrated on the SP task, or in fact his clinical semantic profile. This suggests that the WPV task may require skills other than semantic processing that may be impaired in GB but difficult to identify using currently existing cognitive testing methods. For example, the direct semantic competition caused between two items in WPV is not assessed similarly by other semantic tests, and accurate performance may require a unique combination of cognitive control and access to semantic knowledge that other tests do not directly tap.

11.1.3 Implicit and explicit between-task group comparison

When the implicit and explicit tasks were directly compared to consider coherence in performance across tasks, both groups were significantly less accurate at WPV than SP and WPM, with no difference between SP effect and WPM accuracy. It is therefore hypothesised that WPV is the more sensitive test of semantic processing ability, due to the reduced accuracy observed in comparison to SP and WPM. In light of these findings, theoretical explanations are considered.

Breese and Hillis (2004) found WPV to be a more sensitive task in detecting semantic deficits than WPM, with 78% of PWA trialled performing more poorly on WPV than WPM. The authors propose that due to the yes/no response required, it is a more naturalistic task than WPM which is based on multiple related choices. However, as the control participants and PWA group both made the most errors on this task, it is argued that the WPV task demands are higher than those in the WPM task, resulting in errors in neurologically intact participants. In addition to semantic processing, WPV is assessing additional cognitive skill, including elements of executive functioning such as inhibition, and conflict resolution between two related and competing stimuli. The executive control of semantic processing relates to the potential loss of flexible control of semantic knowledge in aphasia as proposed by Jefferies and Lambon Ralph (2006) and as incorporated in the hub and spoke model of semantic processing (Patterson et al., 2007; Rogers et al., 2004). These authors propose that a control system supports the processing of semantic knowledge dependent on the task or situational context (Thompson-Schill et al., 1997; Wagner et al., 2001), and that if contexts that are well practised will require less control than those which are unfamiliar (Lambon Ralph, 2017). The WPV and WPM tasks are relatively unnatural language tasks, in which individuals are presented with competing related stimuli, in an unusual context, and asked to make a judgement as quickly as possible. Thus higher demands are placed on cognitive control for both PWA and control participants, and this will be harder to recruit in PWA in which left prefrontal and temporo-parietal regions, associated with cognitive control, may be damaged following stroke (Chertkow et al., 1997; Berthier, 2001).

Further explanations of the greater number of errors incurred in the WPV task can be provided by models of semantic memory incorporating competitive selection, which propose that when a concept is activated, activation spreads to representations of similar or associated concepts (e.g. Collins & Loftus, 1975). As the target and related concepts are all activated to some extent, difficulty in selection may arise. Control is required to inhibit related concepts and ensure selection of the target concept, by distinguishing appropriately between competing items e.g. by inhibiting the distractor in WPV.

Semantic refractory effects could also account for the sensitivity of the WPV task. Refractory effects in semantic aphasia have been defined as the decline in semantic access for a period of time after semantic retrieval has occurred (Forde & Humphreys, 1997; Warrington & Crutch, 2004) and a decline in accuracy with rapid, repeated exposure to semantically related trials, for example in WPM tasks (Gardner et al., 2012). People with refractory semantic access difficulties are affected by semantic distance, i.e. the greater the distance between a target and a distractor, the easier the access. For example Warrington and Cipolotti (1996) found that in WPM tasks PWA found it more difficult to choose between semantically related stimuli than more distant ones. The effect has been related to the increase in competition between distractors and targets which does not completely decay between trials, leading to atypical periods of prolonged refractoriness in the semantic system (Campanella & Shallice, 2011). Unlike the SP and WPM tasks, in a WPV task distractors are similar and in direct competition to targets, therefore activation would spread between related concepts and negatively affect access.

A time-pressure element of tasks has been shown to induce aphasic-like refractory errors in unimpaired speakers completing language comprehension tasks (Campanella & Shallice, 2011; Just & Carpenter, 1992; Miyake, Carpenter, & Just, 1994). For example, in a study by Campanella and Shallice (2011), aphasic-like errors were induced in a WPM task when a one second inter-trial interval was eliminated, thus leaving no time gap between trials. The authors propose that refractoriness is therefore a physiological not pathological occurrence, with the findings for refractoriness mirroring those apparent in some PWA with access difficulties, in whom this refractory effect would likely be exaggerated resulting in impaired performance on tasks such as WPV and WPM. Warrington and Cipolotti (1996) also found that rate of presentation of stimuli in WPM influenced the performance of people with semantic access difficulties. Participants performed more accurately when the interval between test items was longer, which Warrington and Cipolotti (1996) explain as time for semantic activation levels to return to a ready state.

A further explanation for the WPV results is the loss of neuro-modulation of semantic conflict caused by competitors. Gotts and Plaut (2002) suggest that neuro-modulatory systems work to reduce refractory effects and enable access of semantic representations, such as efficient discrimination between stimuli which share overlapping features. For example, the role of acetylcholine has been implicated in efficient synaptic functioning within the temporal lobes in transitory conditions of semantic refractoriness (Selden, Gitelman, Salamon-Murayama, Parrish, & Mesulam, 1998). The direct conflict between two very similar concepts in the WPV task would result in impaired semantic processing if the neuro-modulation system was implicated.

It has been argued that refractoriness itself can be explained by impaired semantic control and selection (Jefferies & Lambon Ralph, 2006; Campanella & Shallice, 2011), which can also account for the patterns found in WPV performance. The similarities between the behaviours reported in semantic access PWA and semantic control deficits in PWA have been highlighted by Jefferies et al. (2007) who reported that refractory effects were present in differing degrees in eight PWA assessed on a range of semantic measures. As these participants demonstrated test-retest consistency, unlike classic access patients, the observed refractory effects were proposed to be related to difficulty with executive control of semantic activation as opposed to probabilistic loss of retrieval of semantic information (Jefferies et al., 2007). Badre and Wagner (2007) suggested that the cognitive control system is required to resolve competition between co-activated semantic competitors within demanding tasks, as in the conditions created in the WPV task.

Considering the correlational analyses, the control group showed no relationships between accuracy on the three tasks, perhaps suggesting that the tasks tap different skills or that there is noise in the data, potentially with ceiling effects. The PWA demonstrated a positive relationship of accuracy in the WPV and WPM tasks, which suggests that these tasks require similar semantic processing and other cognitive function requirements; this finding is unsurprising in some respects, due to the similar nature of the tasks of combined picture and written word presentation. The lack of a relationship between the implicit SP and the explicit tasks provides evidence that the tasks are assessing different aspects of semantic processing or recruiting different support systems to complete the tasks. Both groups of participants responded fastest in the SP task, and slowest in the WPM task, despite group differences in response time windows between tasks. The control group were limited to two seconds for SP, to limit strategic processing, and 10 seconds for WPV and WPM, while PWA had unlimited time in which to respond. Despite this, the PWA still showed the same pattern of longest response latency in the WPM task, then WPV, and shortest in the SP task. Potentially, this pattern could be a simple product of the number of stimuli present in each trial, i.e. four in WPM, two in WPV and one in SP, rather than a product of the response time restrictions. Accuracy and response latency on the experimental semantic tasks were not found to be related within either group, suggesting that accuracy is not related to the speed at which participants completed the tasks, and potentially that speed of processing is unrelated to the ability to demonstrate underlying semantic knowledge.

11.1.4 Implicit versus explicit task summary

In relation to research question one, both groups of participants demonstrated semantic priming effects at the participant level. There was a lack of coherence across task performance, with WPV deemed to be the most demanding task resulting in more errors. A subgroup of PWA were found to demonstrate impaired performance on the explicit tasks, yet intact semantic function on the implicit SP task, which provides support for the notion that PWA performance on explicit semantic tasks could be underpinned by the executive control demands of the task; this will be explored further in section 0 in relation to performance on tests of cognition.

11.2 Theoretical implications: stimuli relationship

The second research question sought to add to the debate within the semantic priming literature, with regard to the potential impact of stimuli semantic relationship on semantic functioning. Within the three experimental semantic tasks the effect of different relationships between word pairs was addressed by inclusion of prime-target and distractor-target pairs that were semantically similar with low association (from the same category therefore possess shared features) or associated (different categories but associated by co-occurrence, such as script relations). This additional factor was included in the design due to the lack of consensus within the literature as to whether automatic semantic priming effects occur as a result of semantic priming (Lucas, 2000; Perea & Rosa, 2002), associative priming (Shelton & Martin, 1992), or a combination of both (de Mornay Davies, 1998; Ferrand & New, 2003; Fischler, 1997; Hutchinson, 2003; McRae & Boisvert, 1998). Across the semantic experimental tasks within the current study, at the group level there was no significant difference in processing of semantically similar or associated stimuli, thus providing support for theoretical viewpoints which postulate facilitation from both types of relationship.

In the SP task, significant priming was present for the control group and PWA group at the participant level of analysis, which was the same magnitude for both semantically similar and associated prime-target partners. This is in line with studies of neurologically intact individuals showing a SP effect (Meyer & Schvaneveldt, 1971; Neely, 1977, 1991), with contributions from both shared features of semantically similar items, and lexical or contextual co-occurrence resulting in association strength (Ferrand & New, 2003). The current PWA results update existing findings with neurologically intact individuals, as shown in a review by Hutchison (2003) where more evidence for functional (associated) as opposed to coordinate (semantically similar) prime-target relationships was found. Furthermore, the findings are in contrast to Moss et al. (1995), who reported that for neurologically unimpaired participants, completing a written list presentation SP task, priming occurred independently of association for instrument relationships only, but not for script or co-ordinate relationships. Within the current study co-ordinate and script relationships formed the majority of target pairs within the word lists, therefore the study provides evidence of SP for these types of stimuli relations.

Models of semantic memory can account for semantic or associative priming found within the current SP task. Within localist network models (Collins & Loftus, 1975; Neely, 1977; Posner & Synder, 1975) this would be via automatic spread of activation between primes and semantically related concept nodes in the semantic network or activation of associated lexical nodes due to frequency of co-occurrence (Ferrand & New, 2003), or similar patterns of activation in distributed models (Borowsky & Masson, 1996; Joordens & Becker, 1997; Masson, 1995; McRae, de Sa, & Seidenberg, 1997; Moss et al., 1994; Plaut, 1995; Sharkey & Sharkey, 1992). An example is Plaut's (1995) description of a connectionist model that accounts for semantic and associative effects (also see Lupker, 1984; Shelton & Martin, 1992) in which semantic similarity is measured by amount of overlap in patterns of activated semantic features, and lexical association is encoded via the likelihood of co-occurrence (see also Moss et al., 1994, for similar explanations).

The findings of similar processing for semantically similar and associated stimuli also link to research which has attempted to elucidate the neuroanatomical bases of semantic versus associated knowledge. Mirman and Graziano (2012b) used eye tracking techniques to compare processing of stimuli presented with taxonomically related (semantically similar) versus thematic relationship (associated) distractors in a spoken WPM task. In comparison to neurologically intact control participants, the posterior lesion PWA group with damage to Brodmann area 39 (BA 39) and the surrounding temporo-parietal cortex (TPC) showed reduced and delayed activation of associated relations, but not taxonomic relations. However, the anterior lesion PWA group with damage affecting the inferior frontal gyrus (IFG) and anterior temporal lobe (ATL) but with intact BA 39 did not differ from control participants in activation of thematic relations, but demonstrated longer-lasting activation of taxonomic relations. As a result, the authors argue that taxonomic and thematic semantic knowledge are neuroanatomically and functionally distinct, with a particular role in thematic processing for the temporo-parietal cortex, similar to the role the ATL hub may play for semantic information. The authors suggest that the differences cannot be accounted for via cognitive control due to the lack of explicit semantic processing task requirements within the eye tracking paradigm. According to these results, the patterns of processing for semantically similar and associated items may vary depending on lesion location resulting in individual variability in PWA. There was some evidence of individual variability in response to semantically similar and associated distractors in the current study; however this did not reach significance (this is further discussed in section 11.2.1).

With the use of fMRI techniques, however, it has been demonstrated that the same neural network is engaged in making semantic judgements based on either semantic similarity or associative relationships, including the bilateral ATL, posterior temporal regions and left inferior frontal gyrus (Jackson, Hoffman, Pobric, & Lambon Ralph, 2015). These findings support the hub and spoke model of semantic memory (Patterson et al., 2007; Lambon Ralph et al., 2017) in which conceptually similar and associated stimuli significantly activate the ATL, the amodal representational hub. The importance of thinking based on association may have been underestimated in neurologically intact adults (Lin & Murphy 2001) and Jackson et al. (2015) argue that it is possible that if the two types of semantic and associated information are one and the same i.e. “aspects of the environment that are experienced together when the item is encountered” (p.4330). In this respect, models of semantic memory would encode conceptual associations in the same way that it encodes for shared features, as verbal or nonverbal associative information about a particular concept based on experiential frequency. The current results support this line of reasoning at the group level of analysis, on the basis that there were no differences in the processing of semantically similar and associated stimuli within the SP task.

With regard to the type of distractor present in the WPV task incongruent condition, the only effect of stimuli relationship on accuracy was for the control group at the participant level of analysis; an accuracy advantage for targets presented with an associated distractor compared to semantically similar distractors was found. This suggests that the task demands within the semantically similar condition caused WPV errors in control participants with no semantic impairment, whereas the associated condition did not. The semantically similar items within the WPV task were composed of natural or artificial category coordinates, whereas the associated pairs, the majority of which were script relations, did not share featural overlap. In light of the models of semantic memory discussed, it is possible that it was harder for control participants to reject semantically similar pairs in comparison to associated pairs, due to a larger amount of connections between related nodes as depicted in holistic network models (Collins & Loftus, 1975), or a larger amount of featural overlap and therefore more similar patterns of activation as depicted in distributed models (Plaut, 1995). However, it is of note that the effect was not replicated at the item level of analyses or in the PWA data, and there was no difference in reaction time to targets when paired with semantically similar or associated distractors, mirroring the response latency findings from the SP task. To date, no other studies have published investigations of PWA performance in a WPV task in such depth, hence these are novel findings and data with which to consider the future role of WPV in semantic processing assessment in PWA.

Within the WPM task results were considered in terms of accuracy and response latency in the context of a semantically similar or associated distractor and in terms of type of distractor errors made. The difference in distractor type present did not affect control group accuracy - this is likely due to the low number of errors made in both the semantically similar and associated categories. Control participants did however show a faster response in the presence of an associated distractor. The PWA group showed the reverse pattern to the control group, in that speed of response was not affected by distractor type; however PWA were more accurate in the associated condition. These advantages for associated stimuli could be accounted for in the same way as the control WPV results of greater accuracy for associated items: semantically similar pairs possess more shared semantic features resulting in greater competition in processing in comparison to associated distractors, resulting in a longer decision time. This effect may be heightened in WPM compared to WPV, as all stimuli choices are presented as images which are likely to encourage individuals to focus on lower level perceptual similarities such as featural overlap (Jackson et al., 2015). Eye-tracking research, investigating the effects of thematic (associative) versus specific function (semantic similarity) relationships in WPM arrays, has found that in neurologically intact individuals both types of information are implicitly activated in relation to object concepts, despite not being needed to complete the task, but with slightly different time courses. Activation for associated items occurred earlier and was shorter compared to semantically similar stimuli (Kalénine, Mirman, Middleton, & Buxbaum, 2012), suggesting increased interference for semantically similar items.

Furthermore, in the WPM task although the control group were more accurate overall, when investigating proportion of error types made within each group, both groups made more semantic than phonological or unrelated errors; the latter two error types were rare in both groups. When further deconstructed for comparison, it was apparent that the errors made within the semantic category were instances where the semantically similar distractors were chosen, rather than associated distractors. This can be taken to suggest that both neurologically intact participants and PWA make semantic errors on WPM tests, however to a greater magnitude for PWA. It is hypothesised that in line with distributed models of semantic memory (e.g. Plaut, 1995), the greater number of shared visual features between targets and semantically similar distractors contribute to error responses in this category (Jackson et al., 2015) in comparison to the associated distractors. The findings from the current study suggest that when designing WPM tests, associative items as distractors do not successfully identify semantic level impairments in PWA, and their inclusion in WPM tasks is not warranted.

11.2.1 Individual effects of stimuli relationship in PWA

In line with the second research question, individual PWA variability in response to semantically similar or associated primes was investigated to ascertain if different patterns emerged at the individual as opposed to group level of analysis. Within the aphasia SP literature one study by Tyler et al. (1995) directly controlled for and investigated semantic versus associative relationships between prime-target pairs in PWA, reporting priming for semantic pairings with and without association. However other SP studies with PWA either report findings for stimuli that are both semantically related and associated (e.g. Blumstein et al., 1982; Bushell, 1996; Milberg & Blumstein, 1981) or lack clear criteria. For example, Prather et al., (1997) reported that word pairs used in their study were related but that words were selected based on published association norms, and gives the example *cabbage-lettuce*; therefore a distinction between the two types of relationship is not clearly or consistently reported.

Within the current SP task, all PWA showed a trend of priming in the semantically similar prime condition. In line with previous research demonstrating effects of associative priming in control participants (Fischler, 1977; Hutchison, 2003), ten PWA demonstrated a trend of priming in the associated condition, however the other half showed inhibition caused by associative primes. The current results do not support findings of priming for associated items only (Shelton & Martin, 1992), but are perhaps more in line with studies reporting independent effects of semantic and associative relationships on SP effect (Ferrand & New, 2004; McRae & Boisvert, 1998). The similarity in performance between the different types of stimuli relationship may again be accounted for by shared cortical networks in which semantically similar features and associated conceptual knowledge are encoded similarly based on the frequency with which they have been encountered or occurred (Jackson et al., 2015). Conversely, the individual difference in priming effect for associated items provides some preliminary support for a model in which PWA with anterior versus posterior patterns of left hemisphere neurological damage may respond differently to taxonomic and associated knowledge, as discussed by Mirman and Graziano (2012b). Although the trends of inhibition for associated pairs did not reach significance for any individual PWA, an inhibition effect may be important to consider in therapeutic interventions when selecting appropriate stimuli to facilitate word comprehension or retrieval (Greenwood et al., 2010).

In the WPV task, the main finding at the individual level was of no effects of stimuli relationship on response latency, however one participant, SH, was significantly slower to respond to targets appearing with associated distractors. On inspection of her language and cognitive profile, SH presents with transcortical motor aphasia, generally intact cognitive and executive function ability, and intact lexical semantic processing. Potentially the processing advantage for semantically similar items could be related to her intact semantic knowledge, and the associated distractors may have presented as more ambiguous pairings. Other PWA with similar cognitive and language profiles did not show this effect of stimuli relationship however.

11.2.2 Summary the effect of stimuli relationship

Within the current study, no difference in effect of semantically related or associated stimuli can be reported at the group level. These findings support the view that both types of stimuli are encoded similarly (Jackson et al., 2015). At an individual level for PWA however, findings are less clear cut, with different patterns of facilitation and inhibition apparent for associated items, which supports the view that the site of neurological lesion impacts on individual response to the different stimulus types. Conclusions are cautious in nature due to the potential impact of the reduced number of associated trials in comparison to semantically similar trials across the three semantic tasks, and also due to the lack of consensus in definition of what constitutes semantically similar versus associative relationships and therefore the difficulty in separating the two in testing.

11.3 Relationships between experimental semantic tasks and standard explicit semantic and cognitive assessment

The third research question examined the difference in PWA performance across the three experimental semantic tasks in relation to their language and cognitive profiles, specifically, did performance on language and other cognitive testing predict performance, and if so was executive control of semantics a factor?

11.3.1 Experimental semantic tasks and standard semantic assessments

For the PWA group, the standard tests of semantic processing were compared to accuracy and response latency on the three experimental semantic tasks. No relationship was found between the implicit measure of SP effect and the four semantic measures of CAT WPM composite score, the non-verbal semantic task Pyramids and Palm Trees (PPT), and the PALPA auditory or written synonym judgement. Relationships were found between WPV and WPM in PWA, but these tasks did not show relationships to SP. This suggests that SP may assess semantic knowledge differently to standard or explicit tests due to differences in task requirements, including the difference in implicit versus explicit testing, but also the increased executive control demands associated with judging, selecting and inhibiting multiple semantically related stimuli (Lambon Ralph et al., 2010).

Positive relationships were found between the WPV task accuracy and three semantic measures: written and spoken synonym judgement tasks and the PPT. Positive relationships were found between WPM accuracy and two semantic measures, the CAT WPM composite score and PPT. Where relationships exist it could be suggested that the tasks share common semantic processing requirements, i.e. making semantic judgements in a task with picture stimuli. Synonym judgement tasks may lack a relationship with WPM as they do not involve pictures, and arguably place more complex executive demands than WPM tasks, however the relationship between WPV and synonym judgement may exist as they both involve two competing stimuli present at the same time.

When the same comparisons were made for each subgroup of PWA, different patterns emerged. No relationships were found between experimental semantic task accuracy and semantic test accuracy, apart from a positive relationship between WPM accuracy and auditory synonym judgement for subgroup 2, a finding that was not apparent at the whole group level. This relationship between WPM accuracy and auditory synonym judgement for subgroup 2 is not easy to interpret, and more generally the unclear picture may be due to the lack of control of psycholinguistic variables (Cole-Virtue & Nickels, 2004b) and visual similarity (Cole-Virtue & Nickels, 2004a, Heuer & Hollowell, 2007) in many published tests, therefore resulting in different levels of difficulty. It is also important to note that the relatively small subgroup sizes may have contributed to the differences in the whole group versus the PWA subgroup comparisons.

At the whole group level, no relationships were found between semantic assessment accuracy and response latency in the experimental semantic tasks, apart from a positive relationship between SP response time and auditory synonym judgement accuracy. It could be speculated that the relationship is due to the transient nature of stimuli in the auditory synonym judgement task, requiring rapid processing stimuli, as in the SP task. When analysed as subgroups, this effect was shown to come only from subgroup 1 who also showed a relationship between and auditory synonym judgement accuracy and shorter WPM response times. No relationships were found for PWA subgroup 2. Again, this could be related to poor control of variables between published tests. The main conclusion that can be drawn from these findings is that task response latency is not a useful measure of accuracy of semantic processing in explicit semantic testing methods for PWA (Khwaileh, Body, & Herbert, 2017).

11.3.2 Experimental semantic tasks and cognitive assessments

None of the cognitive or executive function measures were related to the experimental semantic task accuracy at the whole PWA group or subgroup levels. This is in contrast to some evidence of a relationship between aphasic language ability and cognitive ability (Kalbe et al., 2005; Lee & Pyun, 2014) and is problematic in interpretation of theories which link impaired semantic access to impaired executive control (e.g. Baldo et al., 2004; Jefferies & Lambon Ralph, 2006; Wiener et al., 2004). Although language intervention was not the focus of the current study, a relevant aside here is research studies in which cognitive skills have also been found to be related to language recovery post-stroke, including attention (Lambon Ralph et al., 2010), visuospatial working-memory (Seniów et al., 2009) and executive function (Baldo et al., 2005; Hinckley & Carr, 2001; Fillingham et al., 2005a, 2005b, 2006). The present findings suggest however, that performance on the experimental semantic tasks was not related to cognitive ability and executive function, within the remit of the tasks included. For example, a relationship has been reported between semantic ability and the Wisconsin Card Sorting Test in PWA (Jefferies & Lambon Ralph, 2006), and this task was not used within the current study. However a range of additional executive function tasks was included, and did not highlight relationships between cognition and semantic ability.

Relationships were found between SP response latency and four of the six cognitive tests. Shorter SP response times were associated with greater accuracy on the auditory attention measure Elevator Counting composite (TEA), and executive function measures of the Symbol Trails test (CLQT) and Raven’s Matrices. Faster SP response latency was associated with fewer turns and therefore better task performance on the Towers of Hanoi task. When the PWA were analysed in their subgroups the only relationships that remained were between SP response latency and two tests, the Elevator Counting and the Towers of Hanoi, and for subgroup 1 only. These findings could be related to the speed at which stimuli are presented in the SP task, and therefore quicker lexical decisions may be made if participants are equipped with more efficient attention and executive function skills; this would be in line with the subgroup 1 profile of performing similarly to control participants. Despite this suggestion, no relationship was found with the additional measure of executive function, the Brixton spatial anticipation task or digit span, the measure of short-term auditory memory.

No relationships were found between WPV and WPM response latency and the cognitive or executive function measures at the whole PWA group level or at the subgroup levels of analysis. Again, this suggests that response latency in semantic tasks is not clearly related to PWA cognitive skill as measured by standard assessments.

11.3.3 PWA subgroup profiles of semantic and cognitive ability

In an attempt to profile the differences between the two PWA subgroups, their performance on semantic and cognitive testing was compared. Differences on a range of semantic tests were the key defining factors. Subgroup 1 was more accurate than subgroup 2 on two nonverbal semantic measures (PPT and the Camel and Cactus test), a CAT WPM composite score of spoken and written single word comprehension, PALPA auditory synonym judgement (high and low imageability items) and PALPA written synonym judgement; (low imageability items only when separated). The subgroups did not differ on auditory input tasks of minimal pairs and auditory lexical decision, the Category Comprehension Test of word to picture matching in categories (Cambridge Semantic Battery), or the CAT WPM when the spoken and written modality subtests were analysed separately. It is unsurprising that subgroup 2 scored lower on a range of explicit lexical semantic tests involving words and /or pictures, given that they were categorised into the group via poor performance on the explicit experimental semantic tasks, however auditory input problems were not found to contribute towards this difference. The fact that nonverbal tests of semantics were also impaired suggests that access to conceptual knowledge in order to make, at times complex, associations is impaired in subgroup 2. The key defining feature of subgroup 2 therefore continues to be a difficulty displaying semantic knowledge on explicit semantic tasks involving words and/or pictures. Across the range of cognitive tests there were no significant differences in subgroup performance. If the cognitive measures are reliable indicators of visuospatial skills, attention, short term memory and executive function ability, it can therefore be assumed that other cognitive difficulties cannot account for subgroup performance and do not impact on the poor performance of subgroup 2 on explicit semantic tasks.

11.3.4 Summary of semantic and cognitive assessment

At a whole group level, PWA WPV and WPM test accuracy was related to accuracy scores on standard tests of semantics; however this was not the case for SP, an outcome which may have been influenced by the different unit of measurement, i.e. semantic priming effect in ms rather than an accuracy score. The initial findings of impaired semantic performance on explicit tasks which require more cognitive control than implicit methods, provides support for explanations that propose impaired retrieval of task and context relevant aspects of concepts due to impaired executive control of semantics (Jefferies & Lambon Ralph, 2006; Lambon Ralph et al., 2010), however this support is limited by the lack of relationship between cognitive test and semantic task performance. In relation to the cognitive tests used within the current study, which included executive function measures, cognitive task accuracy of PWA did not predict SP, WPV or WPM task performance; the PWA difference in performance between the implicit and explicit semantic measures can therefore not be interpreted solely by an explanation of impaired executive control of semantics.

11.4 Limitations of the research

The study has a number of possible limitations which could affect the generalisability of the findings. These include consideration of control data collection methods for the word list compilation, sample size, participant sample and task construct validity.

11.4.1 Normative data collection methods

The rating scale used to obtain judgements regarding the semantic similarity and visual similarity between word pairs was replicated from similar studies (Moss et al, 1995; Cole-Virtue & Nickels, 2004a), however limitations with the method were identified.

The use of written words within the rating tasks could be problematic where items are homographs. The intended meaning of homographs was not explicitly stated, potentially leading to ambiguity of word meaning and inaccurate ratings for affected word pairs. Consider, for example, in the semantically similar task (SST) the phonologically similar pair *wolf* - *wood* received higher ratings (M = 1.90) than the mean of the whole phonological category (M = 1.19). It is possible that participants were semantically guided to think of the item *wood* as an area of land covered with trees, rather than the intended material wood. Items with higher phonological overlap may also have been a confounding factor, for example, in the semantic similarity task the pair *telephone* - *telescope* was rated higher than the category mean.

Furthermore, in the visual similarity rating task (VST) the use of written words rather than images may have been misleading, with some items being rated higher than the category mean despite the images used in the experimental tasks looking dissimilar. For example, the unrelated pair *cannon* - *microscope* was rated higher (M = 3.05) than the mean of the unrelated category (M = 1.17), potentially due to shared cylindrical shape. However, the images used in the WPM task look dissimilar due to size and colour. In addition, stimuli within the rating task could have been misread, resulting in rating anomalies, for example, one participant queried the word *microscope*, confusing it with the word *telescope,* which may have received a higher visual similarity rating than *microscope* when paired with *cannon*. If available prior to final construction of word lists, it may be more reliable to use images, or images plus the written word as stimuli in rating tasks. This way the ambiguity of the meaning of written words would be avoided, and in the visual similarity task the actual stimuli that will appear in the tests would be rated.

A further limitation is the range of visually similar pairs presented in the VST; because few instances of pairs with extreme visual similarity were included (for example, *peach* and *nectarine*) there may not have been exemplars to fit all points on the scale. This may have led participants to rate pairs with moderate visual similarity more highly, such as the semantically similar pairs that share some visual features. If highly visually similar pairs were included as filler items a more realistic use of the scale could emerge. This could be considered in future studies.

Individual variation between participants was also apparent. Firstly, participants may employ different strategies in completing the semantic similarity rating task. For example, some participants reported rating associated items highly due to contextual co-occurrence, whereas one participant reported rating pairs on the basis of whether one could be visually mistaken for the other (such as *pig* - *horse*). Secondly, as noted by Hata, Homae and Hagiwara (2011), there is individual variation in what individuals perceive to be semantically similar. For example, one participant commented that due to personal religious beliefs they rated *church* - *mosque* as dissimilar in meaning, however were aware that they could be perceived as semantically similar on the basis that they are both buildings for religious worship. A larger sample size would need to be employed to address the issue of individual variability.

Overall, minor methodological alterations could also have been made to obtain ratings, which could be considered in future rating tasks. These include the use of more practice items in an initial familiarisation phase and inclusion of response time limitations to reduce the amount of judgement time available for each item (Pakhomov et al., 2010).

11.4.2 Name agreement

Within the current study a naming task followed by word to picture verification was used to gather name agreement ratings. However as the experimental tasks were testing lexical semantic comprehension as opposed to spoken output, in future standardisation of lexical comprehension tasks, word to picture verification alone could be employed as a measure of lexical item to image correspondence. This would be a more pertinent assessment of written word comprehension, as opposed to the traditional spoken naming task.

11.4.3 Participant and stimuli sample

Aphasia-based research often reports on small sample sizes of individual participants or case-series design. In contrast, the current study recruited 20 PWA to provide larger group data for comparison, as well to provide the potential to isolate individual and subgroup data. However it is recognised that in terms of research sampling, the size of the control and PWA group may lack power, and this may be reflected in some of the findings, for example, the lack of a significant finding at the SP item level of analysis, or relationships between semantic tasks and cognitive tests in the PWA subgroup correlations. Similarly, findings may be limited by a small sample size of test stimuli. Items were limited to 50 per test and were constrained by a range of psycholinguistic variable matching to allow cross-task comparison. One element of this was the inclusion of both semantically similar (*n*=32) versus associated (*n*=18) prime or distractor pairs; there were fewer associated stimuli within each task which may have affected the lack of differentiation between the two.

Returning to consideration of the participant sample, within the PWA sample no neuroimaging data was available to assist with a more specific stroke aphasia diagnoses. PWA were not grouped by aphasia syndrome in the analyses, instead patterns of performance on semantic tests were used to group PWA, as it has been acknowledged that classification of aphasia into syndromes can be unreliable (Gordon, 1998; Ardila, 2010; Marshall, 2010; McNeil & Copeland, 2011), for example, due to variation in criteria or definition of what constitutes fluency and intact repetition. Furthermore, much of the SP literature has focused on the variation in performance of individuals with Broca’s and Wernicke’s aphasia; within the current study no participants met the criteria for Wernicke’s aphasia and only two met the criteria for Broca’s aphasia, therefore due to the limitations of the range within the participant sample, direct comparisons could not be made to these studies.

11.4.4 Individual variation

Although group level SP effects are generally reported in the literature (Yap et al, in press), individual variability in SP has been reported in neurologically unimpaired participants (Stolz, Besner, & Carr, 2005). This may represent individual differences or measurement noise i.e. poor reliability of semantic priming as a method. Stolz et al. (2005) tested the reliability of SP with control participants, measuring within- and between-session reliability in individual performance. Their examination of different experimental SP conditions led to the conclusion that SP lacked reliability in conditions with a short SOA and low relatedness-proportion, i.e. conditions that are required in SP studies to facilitate automatic semantic processing, potentially reflecting a noisy semantic system. When strategic processes could be drawn on, such as expectancy generation (Becker, 1980) or semantic matching (Neely et al., 1989), reliability increased (Stolz et al., 2005). These findings suggest that group level SP effects do not extend to the individual participant level, and when reliance on automatic processing is maximised. If control participants demonstrate individual SP variability, which could be related to variables such as reading ability or attentional processes (Yap et al., in press), it is likely that these factors could account for individual PWA variation, as demonstrated in the current study. However, as discussed by Tan and Yap (2016), the unreliability of the methodology of SP at an individual level could also have a role in the variability reported, which will now be discussed.

11.4.5 Task construct validity

Limitations in drawing conclusions from explicit tests of semantic and cognitive processing have been highlighted. In considering individual variability in SP, it is important to consider that unless the reliability of SP is established as a method, it is difficult to draw conclusions on a lack of relationship between SP and other measures of interest, as this may simply represent low reliability of one or both of the measures of interest (Tan & Yap, 2016). As discussed in section 1.7, a similar issue with the construct validity of cognitive tests is particularly applicable to PWA. Cognitive tests with reduced linguistic load were chosen within the current study to limit interference from impaired language ability of PWA impacting on cognitive task performance; however linguistic demands remain, which are difficult to circumnavigate in design and delivery of nonverbal tests of cognition. For example, PWA are required to firstly comprehend task instructions which may be lengthy or complex to follow, and aspects of performance may still involve elements of lexical processing such as counting the number of non-verbal tones in the Elevator Counting tasks (TEA: Robertson et al., 1994), articulatory rehearsal or repetition in working memory tasks (Mayer & Murray, 2012), or verbal mediation associated with problem solving (Lezak et al., 2004).

Conversely the additional cognitive requirements of semantic tasks are important to consider. Cognitive load within testing is hard to quantify, for example it could be argued that of the experimental semantic tasks, WPM requires the most cognitive load as there are more stimuli to attend to, process and inhibit. However, the control group made more errors on the WPV task, which has fewer competing stimuli but arguably more interference effects between two directly related stimuli. Overlap is also apparent between the construct of implicit testing and cognitive load, for example the SP task arguably has less cognitive load than WPV and WPM as it requires processing of single written words. However it assesses semantic knowledge implicitly through measurement of reaction time to lexical decision, therefore the different contributions of reduced cognitive control and implicit semantic activation are challenging to disentangle.

The validity of cognitive testing is further limited by the difficulty faced in isolating particular cognitive skills for testing, when in reality these cognitive skills are not used separately but interact, for example different types of attention would be needed to engage in any test of cognitive skill, including language, short term memory, and executive function. Similarly, a range of cognitive skills assimilates to form the multidimensional construct of executive functioning (Miyake, Emerson & Friedman, 2000). Some of these difficulties faced in the research of language and other cognition in PWA may account for the variability in findings of a relationship between executive function impairment and semantic ability (e.g. Baldo et al., 2004; Jefferies & Lambon Ralph, 2006; Wiener et al., 2004) or language ability (Kalbe et al., 2005; Lee & Pyun, 2014), and a lack of a relationship between PWA cognitive and language ability in the current study.

11.5 Clinical relevance and application

This study reinforces the recommendation for detailed assessment of language ability in PWA, including implicit and explicit measures of semantic processing. Choice of appropriate SLT intervention is contingent on accurate diagnosis of language impairment. With the explicit testing methods used in the current study PWA presented with impaired single word comprehension characterised by semantic errors, however through implicit testing using a SP method, semantic ability was revealed. Whether reported within research studies or managed in the clinical setting, diagnosis for these participants would therefore have been missing an integral component without this additional information. Unless residual semantic knowledge is uncovered, semantic deficit may be assumed and there runs a risk that SLT and client time and resource is spent targeting a level of processing which is in fact not impaired to the extent that explicit tests portray, and as result outcomes of SLT could be negatively affected. Jefferies (2013) suggests a need for comprehension therapies that minimise executive demands, or conversely, that training in executively-demanding semantic tasks may be appropriate, however the rationale for this is based on a relationship between executive functioning and semantic ability which was not found in the current study, and would need to be considered on a case by case basis.

One proposal to counteract the risk of inaccurate diagnosis would be to include SP and WPV tasks in assessment of semantics in PWA. Limitations with the SP method exist, including the reverse risk of misdiagnosis of impaired semantic functioning in the absence of a semantic priming effect at an individual level. At an individual level control participants with no semantic processing difficulties lacked a significant semantic priming effect and some made errors on the WPV task; this highlights the individual variation in response to SP as a method, and in WPV how the direct competition and interference of two related or associated items may pose more of a cognitive challenge than tests such as WPM or SP. In addition it would be challenging to apply SP in clinical therapeutic settings rather than research testing protocols due to the measures of response latency and subsequent analysis required. Tyler and Moss (1998) emphasise the importance of using both implicit and explicit tasks when assessing comprehension. Although SP as an implicit task can sensitively highlight the underlying automatic conceptual activation, to use language functionally, comprehension requires the synthesis of both unconscious and conscious processing (Marcel, 1983). Activation of a concept alone, as demonstrated via SP, may not be sufficient to achieve functional comprehension in everyday situations. By presenting arrays of related conceptual choices via pictures, neither WPV nor WPM are providing functionally relevant comprehension contexts. Therefore it may be worthwhile future research addressing the need for more functionally relevant alternative comprehension tasks for PWA, for example functional reading tasks.

As discussed, it is vital when designing assessment for PWA that test variables are controlled to avoid impact on test validity (Cole-Virtue & Nickels, 2004b; Heuer & Hallowell, 2007). In consideration of assessment of semantic processing, this study has detailed and accounted for a range of variables which may affect task success, including psycholinguistic matching of stimuli within an array, control of semantic similarity versus association, use of photographic stimuli with reduced background context, and control of visual similarity of items in an array. These are essential considerations in future aphasia test design.

The results are also of direct practical relevance in supporting the daily communication of PWA. Semantic cueing i.e. facilitation of word retrieval by presentation of a semantically similar word (Nessler, 2011), is targeted in therapy for use as a communicative strategy (Wambaugh et al., 2001) or as an element of therapy such as Semantic Feature Analysis (Boyle & Coelho, 1995; Coelho, McHugh, & Boyle, 2000; Lowell, Beeson & Holland, 1995). Bushell (1996) highlights the similarity between semantic cueing and the type of strategic processing which may be utilised in SP tasks with a high relatedness proportion and long ISI/SOA, allowing individuals to generate an expected target from a prime. Under these conditions, participants in the Bushell (1996) study showed inhibitory SP, and it is argued that by creating similar conditions with semantic cueing, an undesired inhibitory effect may occur for word-finding. Participants within the present study were tested under conditions to facilitate unconscious processing, but it is plausible that under conditions encouraging more conscious processing of stimuli, or during long response latency periods, inhibitory priming effects could be found. Also of note, is the observation that individual PWA responded differently to semantically similar and associated primes, with more variability in response to associated primes; this could have clinical implications for choice of semantic cue for facilitation of word finding. For example, individual PWA may be differently primed or inhibited by semantically similar or associated lexical semantic cues.

11.6 Recommendations for future research

The present study has contributed to the evidence base regarding SP in PWA, the need for which has been highlighted by lack of methodological consistency and replication of SP studies with PWA (Carter et al., 2011). As is often the case in research with PWA, further replications of the current results with larger numbers of PWA would be of interest. The present study reported evidence of SP in PWA in conditions proposed to encourage automatic priming of stimuli, including the continuous list paradigm, low relatedness proportion, and short ISI. All PWA within the study were able to engage with the computer task in terms of task speed, the ability to understand task requirements, and signal a response. Firstly, it is likely that a wider-ranging sample, which may include PWA with more severe comprehension or cognitive deficits, would impact on this, and also the findings overall. Secondly, further studies would be required to establish if similar effects of SP are apparent in PWA if a different methodological design was used; for example systematic variation in modality (auditory stimuli, picture stimuli, or cross modality), ISI and paired list presentation.

Moss and Tyler (1995) suggest that when individual PWA fail to demonstrate a SP effect, it is vital to inspect individual control participant results to ascertain if the pattern could be considered typical. Nineteen PWA in the current study demonstrated overall patterns of priming, however the pattern was more mixed in relation to associated prime-target pairs. In future research it is recommended that the difference between semantically similar and associated priming is investigated in PWA with a greater number of stimuli in a SP task, in which inclusion of stimuli would not be as constrained by between-task matching or avoidance of repetition between tasks as in the current study. Within this, further detailed examination could be given to individual control participant patterns of response, in terms of priming or inhibition to semantically similar or associated items.

Several questions remain to be resolved in relation to the explicit tests of semantic processing; in particular whether WPV can be developed into a standardised and clinically useful test in SLT, and also how the choice of distractors included in WPM tasks could be chosen to more accurately measure the semantic processing ability of PWA. Furthermore, although cognitive impairments often co-occur with aphasia (Ivanova et al., 2015; Murray, 2012; Purdy, 2002; Villard & Kiran, 2016), and the role of cognition in stroke recovery (Patel et al, 2002; Zinn et al., 2004) and aphasia rehabilitation (Lambon Ralph et al., 2010) has been highlighted, in the current project there were no relationships between semantic processing ability and cognitive or executive skill as demonstrated via explicit testing. More research in this area is necessary to elucidate the role of cognitive impairment and access to potentially retained semantic knowledge in PWA.

11.7 Summary and conclusions

A range of tests of semantic processing has been developed to compare performance across a range of implicit and explicit tasks, matched for psycholinguistic variables, visual similarity of images, and with separate consideration of semantically similar and associated relationships between lexical items. Implicit SP with methodology to support unconscious processing of semantics has successfully revealed semantic knowledge in PWA. For some PWA this was in line with a profile of intact semantic processing, while for some it was in contrast to impaired performance on explicit tests of semantic processing, potentially suggesting that access to or executive control of knowledge was the basis for the impairment in consciously demonstrating semantic knowledge. No relationships were found between performance on the experimental semantic tasks and tests of other cognition in the current data, therefore clear conclusions regarding links between language and cognitive skills in PWA cannot be drawn. Important clinical implications for PWA result from the findings including insights into different individual responses to semantically similar and associated conceptual relationships, and the recommended development of implicit tasks and functional assessment of semantic processing for PWA.

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APPENDICES

Appendix A: Final word lists

Table A1: Semantic priming task word list

Prime	Frequency	Imageability	Association to target (%)	Target	Frequency	Imageability
taxi	18.61	-	0	limousine	1.75	595
necklace	2.63	606	2	bracelet	1.57	606
ice	41.33	635	2	snow	36.10	597
liver	17.81	571	0	stomach	30.70	551
chair	72.32	610	0	bench	20.61	555
rabbit	14.44	611	1	dog	74.15	636
lantern	2.78	575	3	candle	8.48	594
toe	6.30	620	0	thumb	11.31	599
mosque	3.39	461	-	cathedral	25.57	599
mop	2.59	-	7	broom	3.40	608
cake	24.77	624	4	biscuit	3.95	571
badger	3.83	-	0	squirrel	2.47	642
trumpet	3.71	628	0	clarinet	2.29	593
bee	5.43	623	0	moth	3.04	577
jumper	3.91	-	1	vest	2.72	581
leopard	2.54	635	-	tiger	9.73	606
chisel	1.84	567	0	axe	8.24	597
slipper	1.15	595	2	sock	2.13	553
beaver	1.96	612	5	otter	2.14	572
string	28.94	556	9	rope	15.78	596
curry	5.46	-	0	soup	12.67	604
globe	7.22	583	1	map	44.07	587
potato	7.97	617	0	onion	6.64	617
teddy	6.46	-	-	doll	6.53	565
pig	13.31	635	0	horse	77.88	624
child	253.52	619	7	baby	86.73	608
tusk	0.55	538	-	tooth	6.11	624
moustache	5.88	-	-	beard	9.45	630
fern	2.25	-	-	moss	9.12	569
wren	2.4	551	-	robin	21.74	615
pan	19.74	532	0	kettle	7.50	594
cushion	5.15	-	6	pillow	6.95	624
throne	13.38	-	39	king	174.09	585
cellar	6.53	572	33	wine	64.24	624
sky	50.75	618	7	cloud	22.68	595
ink	8.32	589	30	pen	19.75	576
autumn	42.63	622	4	leaf	16.27	608
easel	1.93	532	11	artist	43.99	600
turtle	2.53	564	6	shell	23.23	581
tea	70.6	599	6	sugar	37.38	595
cow	12.95	632	0	grass	41.09	602
miner	3.48	569	6	pit	17.33	589
hair	140.94	580	2	ribbon	6.78	563
bait	6.07	-	7	hook	14.29	541
handle	38.04	-	2	bucket	9.20	586
soot	1.90	531	1	coal	50.50	581
desert	22.77	-	0	camel	3.65	561
oyster	2.37	521	-	pearl	7.53	590
restaurant	37.01	611	2	menu	16.25	613
camera	27.7	576	1	tripod	1.32	574

Note. Association values were not available in the Edinburgh Associative Thesaurus for eight of the 50 semantically similar or associated primes.

Table A2: Word to picture verification task word list

Distractor	Frequency	Imageability	Association to target (%)	Target	Frequency	Imageability
circle	37.19	591	1	triangle	7.96	597
stapler	0.09	-	-	scissors	4.20	609
wall	118.83	576	1	roof	41.59	604
pilot	35.63	-	0	soldier	18.82	578
lip	16.09	619	7	tongue	24.81	621
sword	14.83	597	4	knife	27.26	633
zebra	2.24	-	0	lion	13.20	626
rake	2.99	550	3	spade	2.97	578
canopy	5.52	-	-	umbrella	8.13	592
pigeon	3.89	610	0	owl	12.59	595
broccoli	1.17	-	-	spinach	2.16	606
plum	2.78	611	0	raspberry	1.63	636
snake	7.88	627	0	crocodile	2.53	601
worm	6.04	578	1	snail	3.04	577
custard	2.00	515	0	gravy	1.81	594
theatre	61.16	-	0	circus	37.19	586
gerbil	0.24	-	-	rat	11.36	588
beaker	1.33	-	3	flask	2.81	614
flannel	2.12	520	7	towel	8.41	570
heart	144.77	617	2	lung	10.06	576
sausage	4.58	-	1	pie	9.85	604
mat	5.63	537	4	rug	7.43	591
crow	3.57	578	0	hawk	4.23	591
silk	23.31	510	1	wool	18.11	586
saliva	2.57	-	0	blood	104.99	620
planet	19.34	578	6	moon	29.24	585
torch	9.02	-	2	lamp	12.97	575
jaw	11.35	573	1	chin	16.45	608
scarf	5.27	-	0	glove	3.88	596
river	100.02	633	0	canal	23.46	588
champagne	19.78	-	0	cider	4.74	626
emerald	2.76	602	-	diamond	11.17	623
thorn	4.78	600	17	rose	118.21	623
sandal	0.40	613	20	foot	71.95	597
tie	28.11	551	12	shirt	26.98	612
alarm	22.98	-	29	bell	34.94	610
meter	4.47	-	1	coin	12.73	603
tights	3.28	-	3	leg	51.83	601
fleece	2.43	547	31	sheep	29.73	596
rubber	15.99	599	-	pencil	10.82	607
medal	12.26	529	16	gold	81.48	594
vodka	3.09	613	28	lime	6.87	563
arm	93.65	593	1	sleeve	9.73	550
donkey	5.21	-	6	cart	9.33	597
pocket	33.48	558	1	wallet	5.89	617
pub	35.96	-	22	beer	33.76	598
wellies	0.90	-	-	puddle	1.73	562
fire	136.16	634	2	hose	2.95	572
hammer	11.67	618	28	nail	7.02	588
wand	1.55	513	6	wizard	4.11	551

Note. Association values were not available in the Edinburgh Associative Thesaurus for seven of the 50 semantically similar or associated distractors.

Table A3: Word to picture matching task word list

Semantic /associative distractor	Frequency	Imageability	Association to target (%)	**Target**	Frequency	Imageability	**Phonological distractor**	Frequency	Imageability	**Unrelated distractor**	Frequency	Imageability
satellite	17.80	.	0	telescope	4.95	596	telephone	81.69	655	cabbage	3.37	573
leek	1.24	540	0	carrot	3.39	577	parrot	3.91	-	skate	1.37	563
hedge	9.65	583	1	tree	63.95	622	tray	13.96	550	shoulder	48.62	577
book	249.51	591	1	magazine	49.41	588	trampoline	0.40	-	cotton	25.41	562
ankle	10.24	613	5	knee	20.64	597	pea	1.74	568	bomb	31.28	606
aeroplane	4.87	-	1	boat	52.74	631	bowl	24.38	579	dress	50.44	595
cuff	1.90	-	2	collar	14.13	582	copper	19.38	548	fountain	7.26	602
hamster	0.97	581	6	mouse	19.16	615	mouth	94.24	613	button	14.63	580
toffee	1.11	-	3	chocolate	17.55	611	toilet	12.59	596	monkey	5.32	588
paw	1.81	-	0	hoof	1.38	598	hood	10.31	558	gym	4.07	613
beetle	2.95	640	2	spider	6.28	597	glider	4.96	-	pyramid	5.64	613
crab	3.42	589	0	lobster	2.72	630	monster	13.37	-	kite	7.79	624
pear	2.09	590	0	apricot	3.46	591	apron	4.82	565	camel	3.65	561
saxophone	0.97	602	2	flute	4.11	581	fruit	41.93	587	wig	3.05	587
lizard	2.29	632	1	toad	3.37	591	road	262.73	609	vest	2.72	581
rifle	7.33	581	0	cannon	7.18	588	salmon	15.1	-	microscope	6.42	617
apple	27.10	637	0	cherry	8.75	582	ferry	14.14	592	axe	8.24	597
jug	5.12	-	0	vase	4.96	563	stars	42.88	-	garlic	8.32	565
fox	19.84	607	2	wolf	8.96	610	wood	75.22	577	sofa	10	597
badge	5.54	519	4	pin	12.82	576	tin	19.13	532	anchor	6.36	561
priest	22.07	568	1	monk	6.93	606	skunk	0.46	652	shower	14.7	615
shoe	11.00	601	4	boot	15.46	604	newt	0.84	472	lightning	0.85	599
bag	46.37	570	0	purse	6.95	567	nurse	34.2	617	bush	40.94	549
witch	6.23	589	0	ghost	13.97	552	toast	9.76	594	shed	21.03	602
television	101.93	-	15	radio	90.10	613	razor	4.25	-	sun	119.67	639
eye	97.46	603	9	nose	41.36	605	note	109.49	503	rain	65.45	618
trousers	20.43	-	1	skirt	14.08	573	scout	3.53	578	nest	15.13	571

pebbles	3.86	-	5	sand	31.51	603	hand	352.9	598	butter	20.73	603
box	82.23	591	0	cage	10.31	585	cape	10.82	566	stool	8.66	584
hutch	0.67	-	-	kennel	1.83	580	funnel	1.63	-	clown	3.57	589
kitten	2.32	639	3	puppy	4.77	635	pepper	10.57	587	nun	4.53	617
flower	24.12	618	1	blossom	3.95	618	possum	0.46	-	oven	12.88	599
lock	23.29	532	45	key	131.33	618	ski	9.21	615	clothes	72.04	629
castle	60.36	-	9	hill	72.12	607	pill	6.18	580	desk	42.88	574
bubbles	4.62	-	6	bath	37.07	601	path	65.24	537	saddle	7.59	578
farmer	24.54	-	1	hay	11.15	597	sleigh	0.44	608	fan	18.14	582
bacon	13.92	-	24	egg	23.76	599	peg	7.28	538	tank	35.45	563
honey	15.08	608	1	bear	57.55	572	bar	78.64	596	wheel	26.01	576
sponge	4.56	577	5	soap	12.75	600	snow	36.10	597	hen	4.27	597
shark	3.37	602	1	ocean	21.64	623	lotion	2.15	497	rice	17.01	506
ducks	6.70	-	1	lake	42.88	616	steak	4.24	647	spot	50.93	507
bow	15.03	546	35	arrow	11.05	619	sparrow	2.07	583	flag	16.11	607
brick	18.71	574	5	cement	7.25	578	tent	11.33	593	drum	10.26	599
food	198.30	539	0	trolley	6.40	585	holly	9.69	-	bandage	1.90	554
astronaut	1.09	-	8	rocket	5.92	612	racket	3.96	530	elephant	9.28	616
meat	35.21	618	1	bone	25.08	567	stone	84.02	585	gift	30.68	553
coffee	60.69	618	0	mug	7.27	574	slug	2.21	-	harp	3.04	621
rubbish	18.49	-	27	bin	8.67	562	fin	3.56	-	caravan	7.78	562
porridge	2.65	-	3	spoon	7.67	584	spine	10.58	-	web	6.38	602
table	201.6	582	0	napkin	2.04	582	pumpkin	0.82	-	chalk	9.66	601

Note. Association values were not available in the Edinburgh Associative Thesaurus for one of the 50 semantically similar distractors, seven phonological distractors and two unrelated distractors.

Table A4: Mean frequency and imageability ratings of stimuli across the experimental semantic tasks

Psycholinguistic variable	**SP targets**	**SP primes**	**WPV targets**	**WPV distractors**	**WPM targets**	**WPM semantic distractors**	**WPM phonological distractors**	**WPM unrelated distractors**
Frequency	22.62	21.60	21.81	20.18	20.85	30.05	32.67	19.03
Imageability	593	587	580	596	595	590	578	587

Appendix B: Information sheet for normative data collection tasks

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Word relatedness survey – information sheet

We are researching understanding of words in people who have had a stroke. The data collected from the survey will be used to design language assessments for people who have language difficulties post-stroke. Lucy Dyson is the researcher carrying out the survey. Lucy is a PhD student in the Department of Human Communication Sciences at The University of Sheffield and a qualified speech and language therapist.

We are looking for people to complete the survey who are aged 18 and over are monolingual UK English speakers with no history of speech, language, literacy difficulties. If you are unsure if you fulfil these criteria please discuss with the researcher.

The survey should only take approximately 20 minutes to complete and involves rating how similar pairs of words are. To complete the questionnaire you can come to the Philippa Cottam Communication Clinic at the University of Sheffield, or Lucy can visit you in the community. The survey can be completed in a group or individual session, you choose.

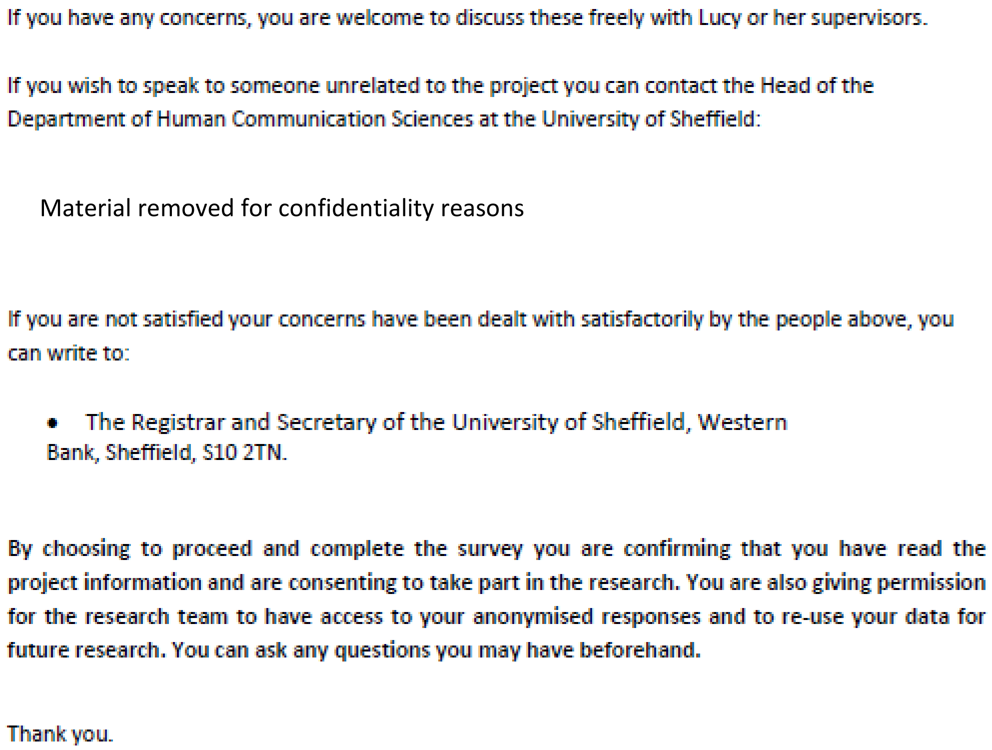
Taking part in the survey is voluntary and you may pause or stop at any point. If you decide to withdraw while completing the survey, your data will be destroyed. Once the survey has been completed the data will not be identifiable and cannot be destroyed. You do not give your name on the survey, but you will be required to provide your sex and age. All data provided will be kept securely on a password-protected computer at the University of Sheffield. All responses you provide will be anonymously coded and no personal identifiers will be published. Data may be used in future research.

The results will be used as part of Lucy Dyson's PhD thesis and may be reported at conferences and written reports in the future.

This study has been approved by the Department of Human Communication Sciences Research Ethics Review Panel and it is supervised by Dr. Ruth Herbert (r.herbert@sheffield.ac.uk) and Dr. Richard Body (r.body@sheffield.ac.uk).

The research is funded by the Stroke Association.

If you have any questions or comments about the research, please contact Lucy Dyson at lucy.dyson@sheffield.ac.uk



If you have any concerns, you are welcome to discuss these freely with Lucy or her supervisors.

If you wish to speak to someone unrelated to the project you can contact the Head of the Department of Human Communication Sciences at the University of Sheffield:

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If you are not satisfied your concerns have been dealt with satisfactorily by the people above, you can write to:

- The Registrar and Secretary of the University of Sheffield, Western Bank, Sheffield, S10 2TN.

By choosing to proceed and complete the survey you are confirming that you have read the project information and are consenting to take part in the research. You are also giving permission for the research team to have access to your anonymised responses and to re-use your data for future research. You can ask any questions you may have beforehand.

Thank you.

Appendix C: Semantic similarity and visual similarity rating task - samples

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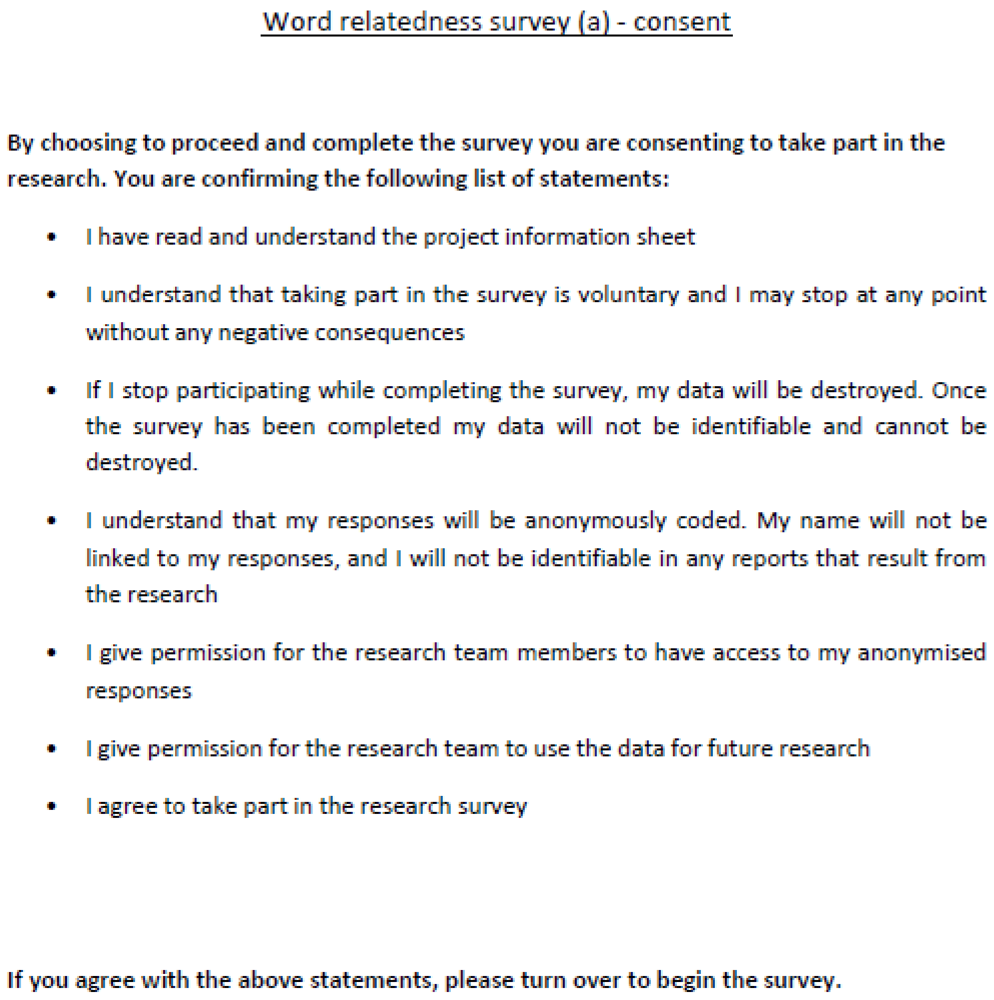


Word relatedness survey (a) - consent

By choosing to proceed and complete the survey you are consenting to take part in the research. You are confirming the following list of statements:

- I have read and understand the project information sheet
- I understand that taking part in the survey is voluntary and I may stop at any point without any negative consequences
- If I stop participating while completing the survey, my data will be destroyed. Once the survey has been completed my data will not be identifiable and cannot be destroyed.
- I understand that my responses will be anonymously coded. My name will not be linked to my responses, and I will not be identifiable in any reports that result from the research
- I give permission for the research team members to have access to my anonymised responses
- I give permission for the research team to use the data for future research
- I agree to take part in the research survey

If you agree with the above statements, please turn over to begin the survey.

Word meaning survey

What is your sex? **Male** **Female**

What is your age? ……………

Introduction

Some words are very similar and related in **meaning**. For example they may be from the same category such as furniture, animals or clothing.

In this survey you are required to decide how **similar in meaning** you think pairs of words are, and rate them using a scale of 1-9:

1	2	3	4	5	6	7	8	9
Not similar in meaning				Moderately similar in meaning				Highly similar in meaning

For example, consider 'cod' and 'haddock'. You may decide that they are very similar and score them highly:

Cod – Haddock 8

Next consider 'cod' and 'guitar'. They are highly dissimilar in meaning, so you might give them a low rating:

Cod – Guitar 1

Now you rate the pairs of words.

Read each pair of words and decide how **similar in meaning** the two things are. Write a number from the 1-9 scale that corresponds with how similar in meaning you think the two words are. You do not need to spend too much time considering each pair.

There are 250 pairs of words to rate. Please turn over to begin.

2

1	2	3	4	5	6	7	8	9
Not similar in meaning				Moderately similar in meaning				Highly similar in meaning

How similar in meaning are:

1 taxi - limousine ____
2 bear - wheel ____
3 ice - snow ____
4 stapler - scissors ____
5 crown- king ____
6 telescope - telephone ____
7 soap - hen ____
8 liver - stomach ____
9 cellar - wine ____
10 chair - bench ____
11 bracelet - braces ____
12 magazine - trampoline ____
13 rabbit - dog ____
14 ocean - rice ____
15 lantern - candle ____
16 sky - cloud ____
17 tree -tray ____
18 toe - thumb ____
19 lake -spot ____
20 ink -pen ____
21 mosque - cathedral ____
22 mop -broom ____
23 knee - pea ____
24 cake - biscuit ____
25 arrow -fork ____
26 cement - drum ____
27 autumn -leaf ____
28 easel - artist ____
29 badger - squirrel ____
30 boat -bowl ____
31 key -ski ____
32 trumpet - clarinet ____
33 bee - moth ____
34 collar -copper ____
35 jumper - vest ____
36 trolley - bandage ____
37 turtle - shell ____
38 tea - sugar ____
39 leopard -tiger ____
40 mouse - mouth ____
41 hill - pill ____
42 chisel - axe ____

Please turn over.

Material removed for confidentiality reasons

Object visual similarity survey (a) - consent

By choosing to proceed and complete the survey you are consenting to take part in the research. You are confirming the following list of statements:

- I have read and understand the project information sheet
- I understand that taking part in the survey is voluntary and I may stop at any point without any negative consequences
- If I stop participating while completing the survey, my data will be destroyed. Once the survey has been completed my data will not be identifiable and cannot be destroyed.
- I understand that my responses will be anonymously coded. My name will not be linked to my responses, and I will not be identifiable in any reports that result from the research
- I give permission for the research team members to have access to my anonymised responses
- I give permission for the research team to use the data for future research
- I agree to take part in the research survey

If you agree with the above statements, please turn over to begin the survey.

Visual similarity survey

What is your sex? **Male** **Female**

What is your age? ……………

Introduction

Objects can look visually similar or dissimilar, for example they may be similar in appearance due to their size, shape and/or colour.

In this survey you are required to rate how **visually similar** pairs of objects are. Please rate the visual similarity using a scale of 1-9:

1	2	3	4	5	6	7	8	9
Not visually similar				Moderately visually similar				Highly visually similar

For example, consider 'ball' and 'house'. They do not look similar in appearance and you would likely give them a very low score:

ball – house 1

Next consider 'ball' and 'orange'. You may decide that they look similar and score them quite highly:

ball – orange 7

Now you rate the pairs of words.

Read each pair of words and decide how **visually similar** the two objects look. Write a number from the 1-9 scale that corresponds with how similar in appearance you think the two things are. You do not need to spend too much time considering each pair.

There are 250 pairs of words to rate. Please turn over to begin.

1	2	3	4	5	6	7	8	9
Not visually similar				Moderately visually similar				Highly visually similar

How visually similar are:

1 taxi - limousine ____

2 bear - wheel ____

3 ice - snow ____

4 stapler - scissors ____

5 crown- king ____

6 telescope - telephone ____

7 soap - hen ____

8 liver - stomach ____

9 cellar - wine ____

10 chair - bench ____

11 bracelet - braces ____

12 magazine - trampoline ____

13 rabbit - dog ____

14 ocean - rice ____

15 lantern - candle ____

16 sky - cloud ____

17 tree -tray ____

18 toe - thumb ____

19 lake -spot ____

20 ink -pen ____

21 mosque - cathedral ____

22 mop -broom ____

23 knee - pea ____

24 cake - biscuit ____

25 arrow -fork ____

26 cement - drum ____

27 autumn -leaf ____

28 easel - artist ____

29 badger - squirrel ____

30 boat -bowl ____

31 key -ski ____

32 trumpet - clarinet ____

33 bee - moth ____

34 collar -copper ____

35 jumper - vest ____

36 trolley - bandage ____

37 turtle - shell ____

38 tea - sugar ____

39 leopard -tiger ____

40 mouse - mouth ____

41 hill - pill ____

42 chisel - axe ____

Please turn over.

Appendix D: Semantic similarity ratings

Table D1: Semantic similarity ratings for target- semantically similar or associated word pairs in SP and WPV tasks

Item	SP task targets	SP task primes	Mean rating	WPV task	WPV distractors	Mean rating
1	**limousine**	taxi	6.65	**triangle**	circle	5.80
2	**bracelet**	necklace	6.45	**scissors**	stapler	5.00
3	**snow**	ice	7.20	**roof**	wall	4.95
4	**stomach**	liver	5.75	**soldier**	pilot	4.65
5	**bench**	chair	7.15	**tongue**	lip	5.45
6	**dog**	rabbit	5.25	**knife**	sword	6.85
7	**candle**	lantern	6.25	**lion**	zebra	5.50
8	**thumb**	toe	6.05	**spade**	rake	5.80
9	**cathedral**	mosque	5.95	**umbrella**	canopy	5.70
10	**broom**	mop	6.40	**owl**	pigeon	6.15
11	**biscuit**	cake	6.55	**spinach**	broccoli	6.80
12	**squirrel**	badger	5.65	**raspberry**	plum	6.80
13	**clarinet**	trumpet	6.60	**crocodile**	snake	6.05
14	**moth**	bee	5.65	**snail**	worm	5.75
15	**vest**	jumper	5.90	**gravy**	custard	5.00
16	**tiger**	leopard	7.00	**circus**	theatre	5.10
17	**axe**	chisel	5.35	**rat**	gerbil	6.65
18	**sock**	slipper	5.50	**flask**	beaker	6.90
19	**otter**	beaver	6.35	**towel**	flannel	6.95
20	**rope**	string	7.05	**lung**	heart	6.65
21	**soup**	curry	4.55	**pie**	sausage	4.75
22	**map**	globe	6.60	**rug**	mat	6.40
23	**onion**	potato	5.50	**hawk**	crow	7.30
24	**doll**	teddy	6.10	**wool**	silk	6.20
25	**horse**	pig	6.15	**blood**	saliva	5.85
26	**baby**	child	6.85	**moon**	planet	6.70
27	**tooth**	tusk	5.65	**lamp**	torch	6.90
28	**beard**	moustache	6.50	**chin**	jaw	7.25
29	**moss**	fern	5.55	**glove**	scarf	5.70
30	**robin**	wren	7.00	**canal**	river	7.15
31	**kettle**	pan	4.45	**cider**	champagne	6.30
32	**pillow**	cushion	8.00	**diamond**	emerald	7.40
33	**king**	throne	6.15	**rose**	thorn	3.90
34	**wine**	cellar	4.30	**foot**	sandal	3.90
35	**cloud**	sky	5.55	**shirt**	tie	5.00
36	**pen**	ink	5.10	**bell**	alarm	6.00
37	**leaf**	autumn	3.85	**coin**	meter	2.95
38	**artist**	easel	4.10	**leg**	tights	4.10
39	**shell**	turtle	3.85	**sheep**	fleece	3.85
40	**sugar**	tea	3.95	**pencil**	rubber	4.30
41	**grass**	cow	3.10	**gold**	medal	5.10
42	**pit**	miner	3.95	**lime**	vodka	3.35
43	**ribbon**	hair	2.60	**sleeve**	arm	4.55
44	**hook**	bait	4.65	**cart**	donkey	3.50
45	**bucket**	handle	3.10	**wallet**	pocket	5.05
46	**coal**	soot	5.35	**beer**	pub	5.15
47	**camel**	desert	3.45	**puddle**	wellies	3.75
48	**pearl**	oyster	4.40	**hose**	fire	3.75
49	**menu**	restaurant	3.70	**nail**	hammer	4.40
50	**tripod**	camera	3.85	**wizard**	wand	3.65

Note. Rating scale: 1 = not similar in meaning, 5 = moderately similar in meaning, 9 = highly similar in meaning.

Table D2: Semantic similarity ratings for target-distractor word pairs in the WPM task

Item	Target	Semantic or associated	Mean rating	Phonological	Mean rating	Unrelated	Mean rating
1	**telescope**	satellite	4.35	telephone	2.25	cabbage	1.05
2	**carrot**	leek	6.70	parrot	1.15	skate	1.00
3	**tree**	hedge	5.90	tray	1.25	shoulder	1.05
4	**magazine**	book	6.60	trampoline	1.25	cotton	1.05
5	**knee**	ankle	5.40	pea	1.05	bomb	1.00
6	**boat**	aeroplane	4.85	bowl	1.50	dress	1.05
7	**collar**	cuff	5.25	copper	1.10	fountain	1.05
8	**mouse**	hamster	7.00	mouth	1.10	button	1.20
9	**chocolate**	toffee	6.20	toilet	1.10	monkey	1.15
10	**hoof**	paw	5.90	hood	1.05	gym	1.05
11	**spider**	beetle	6.05	glider	1.15	pyramid	1.00
12	**lobster**	crab	6.95	monster	1.55	kite	1.00
13	**apricot**	pear	6.35	apron	1.20	camel	1.30
14	**flute**	saxophone	6.60	fruit	1.10	wig	1.10
15	**toad**	lizard	5.85	road	1.20	vest	1.00
16	**cannon**	rifle	4.75	salmon	1.10	microscope	1.15
17	**cherry**	apple	6.05	ferry	1.05	axe	1.00
18	**vase**	jug	6.95	stars	1.05	garlic	1.05
19	**wolf**	fox	6.40	wood	1.90	sofa	1.00
20	**pin**	badge	5.45	tin	1.20	anchor	2.05
21	**monk**	priest	6.65	skunk	1.20	shower	1.00
22	**boot**	shoe	7.70	newt	1.05	lightening	1.05
23	**purse**	bag	6.25	nurse	1.10	bush	1.00
24	**ghost**	witch	3.40	toast	1.10	shed	1.00
25	**radio**	television	5.50	razor	1.15	sun	1.20
26	**nose**	eye	5.45	note	1.05	rain	1.10
27	**skirt**	trousers	5.65	scout	1.15	nest	1.00
28	**sand**	pebbles	5.35	hand	1.15	butter	1.10
29	**cage**	box	3.75	cape	1.15	stool	1.15
30	**kennel**	hutch	6.40	funnel	1.15	clown	1.00
31	**puppy**	kitten	5.75	pepper	1.05	nun	1.05
32	**blossom**	flower	7.35	possum	1.05	oven	1.00
33	**key**	lock	4.65	ski	1.10	clothes	1.30
34	**hill**	castle	2.40	pill	1.05	desk	1.00
35	**bath**	bubbles	4.00	path	1.10	saddle	1.00
36	**hay**	farmer	3.65	sleigh	1.25	fan	1.00
37	**egg**	bacon	4.80	peg	1.05	tank	1.05
38	**bear**	honey	2.30	bar	1.00	wheel	1.05
39	**soap**	sponge	3.45	snow	1.25	hen	1.05
40	**ocean**	shark	3.20	lotion	1.25	rice	1.10
41	**lake**	ducks	3.05	steak	1.00	spot	1.15
42	**arrow**	bow	4.25	sparrow	1.40	flag	1.85
43	**cement**	brick	5.00	tent	1.00	drum	1.40
44	**trolley**	food	2.50	holly	1.05	bandage	1.40
45	**rocket**	astronaut	4.20	racket	1.20	elephant	1.00
46	**bone**	meat	4.30	stone	1.70	gift	1.30
47	**mug**	coffee	3.80	slug	1.10	harp	1.05
48	**bin**	rubbish	4.50	fin	1.00	caravan	1.65
49	**spoon**	porridge	2.95	spine	1.00	web	1.15
50	**napkin**	table	3.60	pumpkin	1.50	chalk	1.00

Note. Rating scale: 1 = not similar in meaning, 5 = moderately similar in meaning, 9 = highly similar in meaning.

Appendix E: Visual similarity ratings

Visual similarity ratings for target-distractor pairs in the WPM task

Item	Target	Semantic or associated	Mean rating	Phonological	Mean rating	Unrelated	Mean rating
1	**telescope**	satellite	3.05	telephone	1.55	cabbage	1.05
2	**carrot**	leek	4.05	parrot	1.15	skate	1.00
3	**tree**	hedge	5.30	tray	1.05	shoulder	1.05
4	**magazine**	book	6.80	trampoline	1.20	cotton	1.05
5	**knee**	ankle	5.40	pea	1.25	bomb	1.10
6	**boat**	aeroplane	2.25	bowl	3.05	dress	1.15
7	**collar**	cuff	5.05	copper	1.15	fountain	1.15
8	**mouse**	hamster	7.70	mouth	1.25	button	1.15
9	**chocolate**	toffee	6.05	toilet	1.00	monkey	1.15
10	**hoof**	paw	4.90	hood	1.10	gym	1.00
11	**spider**	beetle	5.80	glider	1.00	pyramid	1.10
12	**lobster**	crab	7.00	monster	3.40	kite	1.05
13	**apricot**	pear	4.45	apron	1.00	camel	1.15
14	**flute**	saxophone	3.70	fruit	1.05	wig	1.00
15	**toad**	lizard	4.35	road	1.05	vest	1.00
16	**cannon**	rifle	4.05	salmon	1.10	microscope	3.05
17	**cherry**	apple	4.10	ferry	1.00	axe	1.00
18	**vase**	jug	5.85	stars	1.15	garlic	1.20
19	**wolf**	fox	6.60	wood	1.05	sofa	1.05
20	**pin**	badge	3.35	tin	1.05	anchor	1.90
21	**monk**	priest	7.35	skunk	1.10	shower	1.05
22	**boot**	shoe	7.35	newt	1.00	lightening	1.00
23	**purse**	bag	6.40	nurse	1.05	bush	1.05
24	**ghost**	witch	2.70	toast	1.00	shed	1.00
25	**radio**	television	3.35	razor	1.05	sun	1.10
26	**nose**	eye	1.30	note	1.10	rain	1.05
27	**skirt**	trousers	2.70	scout	1.00	nest	1.10
28	**sand**	pebbles	3.50	hand	1.00	butter	1.90
29	**cage**	box	4.85	cape	1.00	stool	1.40
30	**kennel**	hutch	6.50	funnel	1.40	clown	1.00
31	**puppy**	kitten	4.95	pepper	1.00	nun	1.10
32	**blossom**	flower	6.95	possum	1.00	oven	1.00
33	**key**	lock	1.40	ski	1.20	clothes	1.00
34	**hill**	castle	1.30	pill	1.20	desk	1.05
35	**bath**	bubbles	1.45	path	1.00	saddle	1.20
36	**hay**	farmer	1.00	sleigh	1.10	fan	1.05
37	**egg**	bacon	1.50	peg	1.05	tank	1.05
38	**bear**	honey	1.00	bar	1.05	wheel	1.05
39	**soap**	sponge	3.70	snow	1.65	hen	1.10
40	**ocean**	shark	1.05	lotion	1.80	rice	1.10
41	**lake**	ducks	1.05	steak	1.15	spot	1.05
42	**arrow**	bow	1.55	sparrow	1.15	flag	1.95
43	**cement**	brick	2.55	tent	1.00	drum	1.20
44	**trolley**	food	1.00	holly	1.00	bandage	1.05
45	**rocket**	astronaut	1.15	racket	1.15	elephant	1.00
46	**bone**	meat	1.90	stone	3.20	gift	1.05
47	**mug**	coffee	1.15	slug	1.00	harp	1.05
48	**bin**	rubbish	1.20	fin	1.00	caravan	1.45
49	**spoon**	porridge	1.20	spine	1.55	web	1.00
50	**napkin**	table	1.40	pumpkin	1.10	chalk	1.20

Note. Rating scale: 1 = not visually similar, 5 = moderately visually similar, 9 = highly visually similar.

Appendix F: Images replaced after name agreement

Images replaced in the WPM task following name agreement

Item	**Stimuli type**	**Original image name agreement**	**New image name agreement**	**Rationale for substitution**
cement	Target	.50	1.00	The original image presented the cement on a trowel, which participants often named instead.
sleigh	Phonological distractor	.75	1.00	The original image was often named as *sledge*, therefore a more traditional *sleigh* image was included.
rain	Unrelated distractor	.65	1.00	It is difficult to locate a recognisable photographic image of *rain* other distracting objects in the scene, therefore a colour line drawing of rain was trialled.
sun	Unrelated distractor	1.00	1.00	The photograph was replaced with a colour line drawing of a *sun*, as 8/20 participants named the original as *sunset*.
bag	Semantic distractor	1.00	1.00	A more generic looking *bag* was trialled, as 10/20 participants named the original item as *handbag*.

Appendix G: Name agreement accuracy by item

Word to picture verification target stimuli

Item	Total participants	Accurate on first attempt or self-correct (%)	Accurate after prompt (%)	Accurate after word to picture verification (%)
triangle	20	1.00	-	-
scissors	20	1.00	-	-
roof	20	1.00	-	-
soldier	20	1.00	-	-
tongue	20	1.00	-	-
knife	20	1.00	-	-
lion	20	1.00	-	-
spade	20	.95	1.00	-
umbrella	20	1.00	-	-
owl	20	1.00	-	-
spinach	20	.90	.90	-
raspberry	20	1.00	-	-
crocodile	20	.85	-	-
snail	20	1.00	-	-
gravy	20	1.00	-	-
circus	20	.85	.95	-
rat	20	.90	.95	-
flask	20	.95	-	-
towel	20	1.00	-	-
lung	20	1.00	-	-
pie	20	1.00	-	-
rug	20	.80	.90	
hawk	20	**.25**	**.40**	1.00
wool	20	1.00	-	-
blood	20	**.50**	**.75**	1.00
moon	20	1.00	-	-
lamp	20	1.00	-	-
chin	20	1.00	-	-
glove	20	1.00	-	-
canal	20	**.35**	.90	-
diamond	20	1.00	-	-
cider	20	.95	1.00	-
rose	20	1.00	-	-
foot	20	.95	1.00	-
shirt	20	1.00	-	-
bell	20	1.00	-	-
coin	20	.95	.95	-
leg	20	.85	.95	-
sheep	20	1.00	-	-
pencil	20	1.00	-	-
gold	20	1.00	-	-
lime	20	1.00	-	-
sleeve	20	.90	.90	-
cart	20	.90	.95	-
wallet	20	.95	.95	-
beer	20	1.00	-	-
puddle	20	1.00	-	-
hose	20	1.00	-	-
nail	20	1.00	-	-
wizard	20	1.00	-	-

Word to picture matching target stimuli

Item	Total participants	Accurate on first attempt or self-correct (%)	Accurate after prompt (%)	Accurate after word to picture verification (%)
telescope	20	1.00	-	-
carrot	20	1.00	-	-
tree	20	1.00	-	-
magazine	20	.85	.90	-
knee	20	1.00	-	-
boat	20	.90	1.00	-
collar	20	1.00	-	-
mouse	20	1.00	-	-
chocolate	20	1.00	-	-
hoof	20	1.00	-	-
spider	20	1.00	-	-
lobster	20	1.00	-	-
apricot	20	**.50**	**.70**	1.00
flute	20	1.00	-	-
toad	20	.90	1.00	-
cannon	20	1.00	-	-
vase	20	1.00	-	-
cherry	20	1.00	-	-
wolf	20	.95	1.00	-
pin	20	1.00	-	-
monk	20	.95	1.00	-
boot	20	1.00	-	-
purse	20	1.00	-	-
ghost	20	1.00	-	-
radio	20	1.00	-	-
nose	20	1.00	-	-
skirt	20	1.00	-	-
cage	20	1.00	-	-
sand	20	1.00	-	-
lake	20	.95	1.00	-
puppy	20	1.00	-	-
blossom	20	.85	.90	-
key	20	1.00	-	-
hill	20	.85	1.00	-
bath	20	1.00	-	-
hay	20	.85	.90	-
egg	20	1.00	-	-
bear	20	1.00	-	-
soap	20	1.00	-	-
ocean	20	**.15**	.85	-
kennel	20	.95	1.00	-
arrow	20	.95	.95	-
trolley	20	1.00	-	-
rocket	20	1.00	-	-
bone	20	1.00	-	-
mug	20	.90	.95	-
bin	20	1.00	-	-
spoon	20	1.00	-	-
napkin	20	.95	.95	-
cement	18	.94	1.00	-

Semantically similar or associated distractors (WPM task)

Item	Total participants	Accurate on first attempt or self-correct (%)	Accurate after prompt (%)	Accurate after word to picture verification (%)
satellite	20	.90	1.00	-
leek	20	1.00	-	-
hedge	20	.95	.95	-
book	20	1.00	-	-
ankle	20	.95	1.00	-
cuff	20	.80	.90	-
aeroplane	20	1.00	-	-
hamster	20	.90	.95	-
toffee	20	**.35**	.90	-
paw	20	1.00	-	-
beetle	20	1.00	-	-
crab	20	1.00	-	-
pear	20	1.00	-	-
saxophone	20	1.00	-	-
lizard	20	.90	1.00	-
rifle	20	**.35**	.80	-
apple	20	1.00	-	-
jug	20	1.00	-	-
fox	20	.95	.95	-
badge	20	.85	1.00	-
priest	20	.85	.95	-
shoe	20	.95	1.00	-
witch	20	1.00	-	-
television	20	1.00	-	-
eye	20	1.00	-	-
trousers	20	1.00	-	-
pebbles	20	.80	.85	-
box	20	1.00	-	-
hutch	20	.95	1.00	-
kitten	20	.95	.95	-
flower	20	.95	1.00	-
lock	20	**.60**	.95	-
castle	20	1.00	-	-
bubbles	20	1.00	-	-
farmer	20	1.00	-	-
bacon	20	1.00	-	-
honey	20	1.00	-	-
sponge	20	1.00	-	-
shark	20	1.00	-	-
ducks	20	1.00	-	-
bow	20	1.00	-	-
food	20	**.65**	.95	-
brick	20	1.00	-	-
astronaut	20	.95	1.00	-
meat	20	.95	1.00	-
coffee	20	.80	1.00	-
rubbish	20	.85	1.00	-
porridge	20	1.00	-	-
table	20	1.00	-	-
bag	20	1.00	-	-

Phonological distractor stimuli (WPM task)

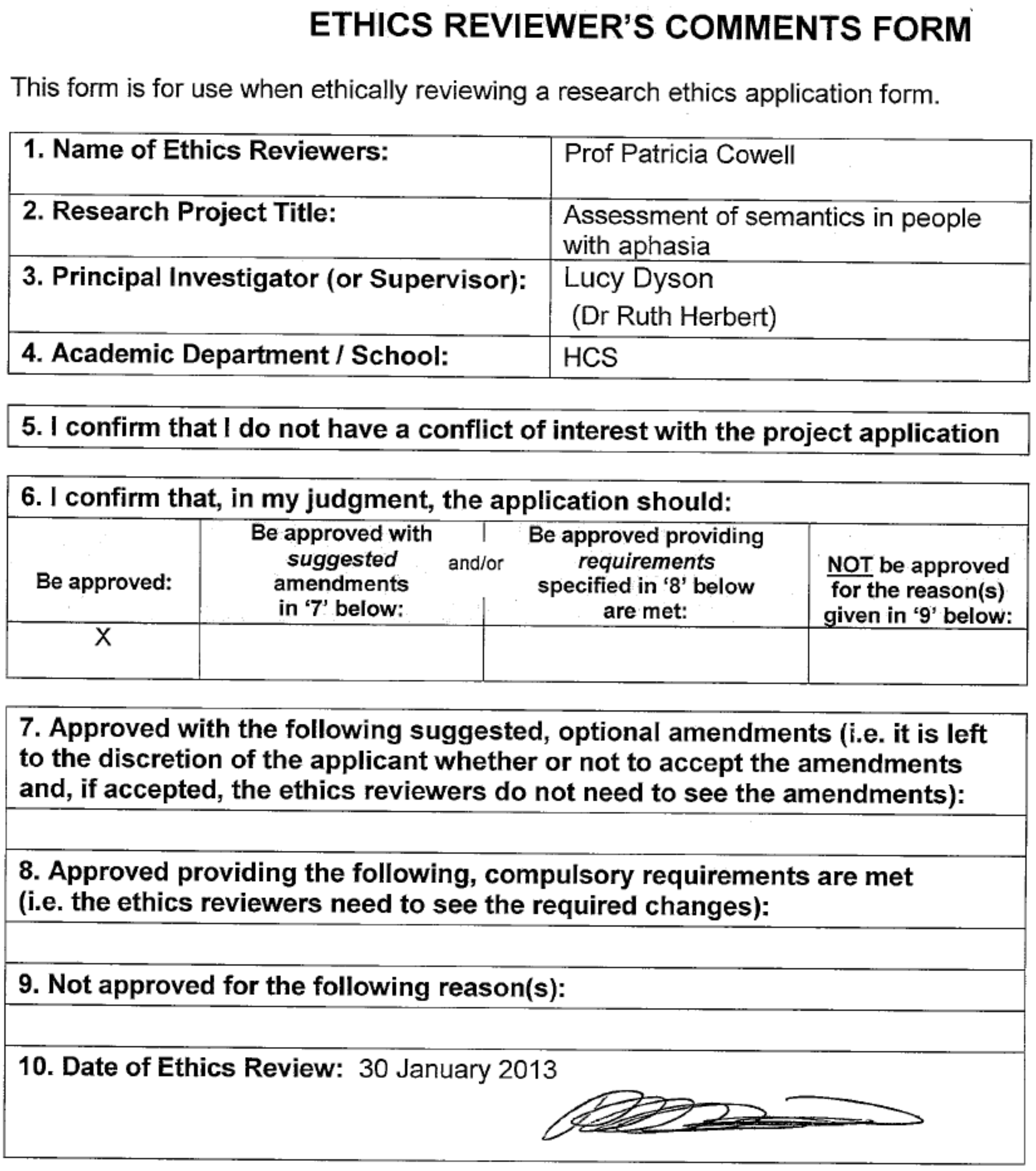
Item	Total participants	Accurate on first attempt or self-correct (%)	Accurate after prompt (%)	Accurate after word to picture verification (%)
telephone	20	1.00	-	-
parrot	20	1.00	-	-
tray	20	1.00	-	-
pea	20	1.00	-	-
bowl	20	1.00	-	-
copper	20	**.35**	**.60**	1.00
mouth	20	.95	1.00	-
trampoline	20	1.00	-	-
toilet	20	.95	1.00	-
hood	20	.95	.95	-
glider	20	**.55**	**.65**	1.00
monster	20	.90	.95	-
apron	20	1.00	-	-
fruit	20	1.00	-	-
road	20	1.00	-	-
salmon	20	.80	1.00	-
ferry	20	**.65**	.80	-
stars	20	1.00	-	-
wood	20	.90	.95	-
tin	20	1.00	-	-
skunk	20	.85	.95	-
newt	20	.80	.90	-
toast	20	1.00	-	-
razor	20	1.00	-	-
note	20	.90	.95	-
scout	20	.95	1.00	-
hand	20	1.00	-	-
nurse	20	1.00	-	-
cape	20	.85	.90	-
funnel	20	1.00	-	-
pepper	20	.90	1.00	-
ski	20	.90	.90	-
pill	20	**.65**	.90	-
peg	20	1.00	-	-
bar	20	1.00	-	-
possum	20	**.25**	**.25**	1.00
lotion	20	**.20**	**.50**	1.00
steak	20	.90	.95	-
path	20	.95	.95	-
sparrow	20	**.35**	**.65**	1.00
tent	20	1.00	-	-
holly	20	.90	.95	-
stone	20	**.60**	.80	-
fin	20	.95	1.00	-
spine	20	1.00	-	-
slug	20	1.00	-	-
sleigh	16	.81	1.00	-
pumpkin	16	1.00	-	-
snow	16	.81	.94	-
racket	16	1.00	-	-

Unrelated distractor stimuli (WPM task)

Item	Total participants	Accurate on first attempt or self-correct (%)	Accurate after prompt (%)	Accurate after word to picture verification (%)
flag	20	1.00	-	-
cabbage	20	.95	.95	-
skate	20	1.00	-	-
bomb	20	1.00	-	-
cotton	20	**.50**	**.65**	1.00
shoulder	20	1.00	-	-
dress	20	1.00	-	-
fountain	20	1.00	-	-
button	20	1.00	-	-
monkey	20	1.00	-	-
gym	20	.95	1.00	-
pyramid	20	1.00	-	-
kite	20	1.00	-	-
camel	20	1.00	-	-
wig	20	1.00	-	-
vest	20	1.00	-	-
microscope	20	.95	.95	-
axe	20	1.00	-	-
garlic	20	1.00	-	-
sofa	20	1.00	-	-
anchor	20	1.00	-	-
shower	20	1.00	-	-
lightning	20	1.00	-	-
bush	20	.90	.95	-
shed	20	1.00	-	-
nest	20	.95	.95	-
butter	20	1.00	-	-
stool	20	1.00	-	-
clown	20	1.00	-	-
nun	20	1.00	-	-
oven	20	1.00	-	-
clothes	20	**.65**	.80	-
desk	20	1.00	-	-
saddle	20	.95	.95	-
fan	20	1.00	-	-
tank	20	.95	.95	-
wheel	20	1.00	-	-
hen	20	**.45**	1.00	-
rice	20	.95	.95	-
spot	20	.95	1.00	-
drum	20	1.00	-	-
bandage	20	.95	1.00	-
elephant	20	1.00	-	-
gift	20	**.00**	**.75**	1.00
harp	20	1.00	-	-
caravan	20	1.00	-	-
web	20	0.95	.95	-
chalk	20	1.00	-	-
rain	16	1.00	-	-
sun	10	1.00	-	-
Total with >80% accuracy (250)		229	240	250
Proportion with >80% accuracy		**.92**	**.96**	**1.00**
Total with <80% accuracy (250)		21	10	0
Proportion with <80% accuracy		**.08**	**.04**	**.00**

Note. Underlined and emboldened scores represent those items with <80% accuracy.

Appendix H: Ethical approval



ETHICS REVIEWER'S COMMENTS FORM

This form is for use when ethically reviewing a research ethics application form.

1. Name of Ethics Reviewers:	Prof Patricia Cowell
2. Research Project Title:	Assessment of semantics in people with aphasia
3. Principal Investigator (or Supervisor):	Lucy Dyson (Dr Ruth Herbert)
4. Academic Department / School:	HCS

5. I confirm that I do not have a conflict of interest with the project application

6. I confirm that, in my judgment, the application should:

Be approved:	Be approved with *suggested* amendments in '7' below:	and/or	Be approved providing *requirements* specified in '8' below are met:	<u>NOT</u> be approved for the reason(s) given in '9' below:
X				

7. Approved with the following suggested, optional amendments (i.e. it is left to the discretion of the applicant whether or not to accept the amendments and, if accepted, the ethics reviewers do not need to see the amendments):

8. Approved providing the following, compulsory requirements are met (i.e. the ethics reviewers need to see the required changes):

9. Not approved for the following reason(s):

10. Date of Ethics Review: 30 January 2013

Appendix I: Control participant information and consent form

The
University
Of
Sheffield.

Material removed for confidentiality reasons

Research project information sheet – control participants

Testing understanding of word meaning

This information sheet describes a research project at the University of Sheffield, looking at language after stroke.

We are inviting people to take part in the project. It is important for individuals to understand why the research is being done and what it will involve.

What is the study about?
We are researching understanding of words in people who have had a stroke. After having a stroke some people have aphasia, which means they can have difficulty understanding or producing spoken or written words and sentences. We are investigating new tests of word comprehension in people with aphasia, but prior to this we need to investigate how healthy participants perform on the same novel assessments.

We hope this will improve understanding about language comprehension difficulties after stroke. This might then improve assessment and speech and language therapy choices in the future.

Who is taking part?
We are looking for healthy control participants to take part, aged from 40 years upwards.

Deciding whether to take part
Participation is voluntary. Anyone who decides to take part will be given an information sheet and sign a consent form. You can withdraw from the study at any time and without giving a reason. If you withdraw from the study, we will ask if you want the information already collected to be destroyed.

What will happen?
You can come to the Philippa Cottam Communication Clinic at the University of Sheffield, or we can visit you in the community. There will be no monetary compensation for your time or travel expenses.

There will be one assessment session lasting approximately 1 hour. Participants will complete three short tests on a laptop computer which involve reading words and making a response. There will also be assessment of reading or repeating single words which will be audio-recorded for analysis purposes only. The sessions will be led by Lucy Dyson, a qualified speech and language therapist and member of the Health and Care Professions Council.

What will happen to the data and recordings?
The researcher, Lucy Dyson, will securely keep all electronic data and audio-recordings on her password-protected computer at the University of Sheffield. Copies of electronic data, recordings and paper-based information will be kept securely in a locked filing cabinet.

Research data will be used in analysis, reports and presentations. Audio-recordings will only be used for analysis purposes within the project team. No other use will be made of your data without your written permission, and no one outside the project will be allowed access to data. You choose if your data can be used in future research or not. If you choose for your data not to be used in future research then it will be destroyed at the end of the study.

Participants names or other personal information such as date of birth will not be known to anyone other than Lucy Dyson. Data will be anonymised: names will not be used in any test data collected, instead participants will be assigned with a number. Data may be used in research publications, but you will not be identifiable as names and personal information will not be used.

What will happen to the results of the study?
The results will be used as part of Lucy Dyson's PhD thesis and may be reported at conferences and written reports in the future. In any report of the study, we will ensure that you cannot be identified.

Will taking part be kept confidential?
Yes. All information will be confidential. Your name, and other personal details will not be revealed to any person outside the project.

What are the potential disadvantages and risks of taking part?
There are unlikely to be specific risks or disadvantages to taking part. Sessions will involve completing paper-based assessments and simple tasks on a computer. You may become frustrated if you are unfamiliar with using a computer. However, we will provide training, practise and support to minimise the risk of this occurring. You can request breaks or stop at any time should you wish.

What are the potential benefits of taking part?
Taking part in the study will not have direct benefit to you. It provides an opportunity to take part in a research project, the results of which will further our knowledge about language difficulties post-stroke and may help people with aphasia in the future.

Who is funding the research?
The project is funded by the Stroke Association.

Ethical approval
This study is approved by the Department of Human Communication Sciences Research Ethics Review Panel.

Research Team
Lucy Dyson is a PhD student in the Department of Human Communication Sciences at The University of Sheffield. Dr Ruth Herbert and Dr Richard Body are senior lecturers supervising Lucy's PhD. All team members are qualified speech and language therapists registered with the Health and Care Professions Council.

Researcher: Lucy Dyson

Material removed for confidentiality reasons

Supervisors: Dr Ruth Herbert

Dr Richard Body

Further information
For further information please contact the researcher, Lucy Dyson.

What if there is a problem or I want to make a complaint?
If you have any concerns, you are welcome to discuss these freely with Lucy or her supervisors.

If you wish to speak to someone unrelated to the project you can contact the Head of the Department of Human Communication Sciences at the University of Sheffield:

Material removed for confidentiality reasons

If you are not satisfied your concerns have been dealt with satisfactorily by the people above, you can write to:

- The Registrar and Secretary of the University of Sheffield, Western Bank, Sheffield, S10 2TN.

Thank you for reading this information sheet

The
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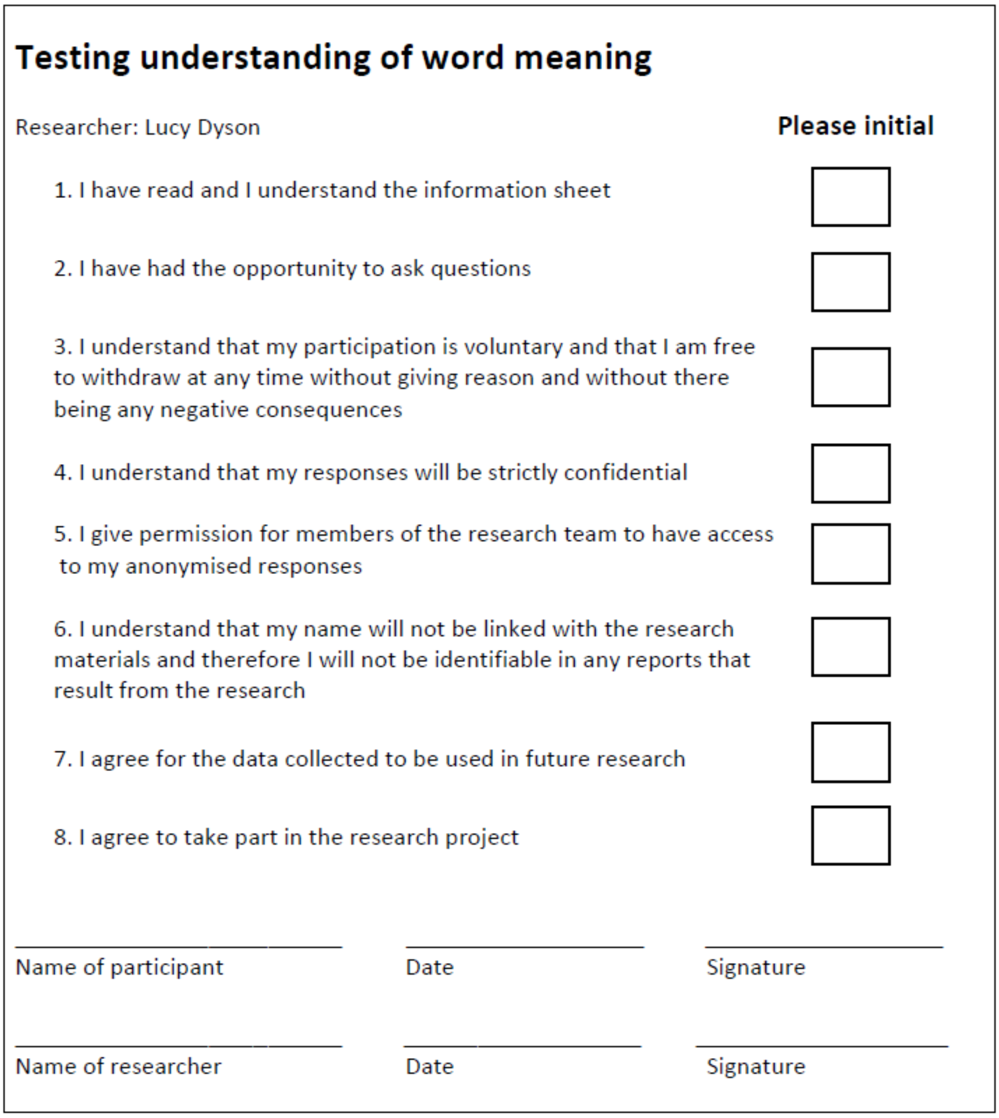
Of
Sheffield.

Material removed for confidentiality reasons

Control participant consent form



Testing understanding of word meaning

Researcher: Lucy Dyson

Please initial

1. I have read and I understand the information sheet ☐
2. I have had the opportunity to ask questions ☐
3. I understand that my participation is voluntary and that I am free to withdraw at any time without giving reason and without there being any negative consequences ☐
4. I understand that my responses will be strictly confidential ☐
5. I give permission for members of the research team to have access to my anonymised responses ☐
6. I understand that my name will not be linked with the research materials and therefore I will not be identifiable in any reports that result from the research ☐
7. I agree for the data collected to be used in future research ☐
8. I agree to take part in the research project ☐

______________________ ______________________ ______________________

Name of participant Date Signature

______________________ ______________________ ______________________

Name of researcher Date Signature

Appendix J: PWA information, consent form and family information

The
University
Of
Sheffield.

Material removed for confidentiality reasons

Language assessment for people with aphasia

PhD student:

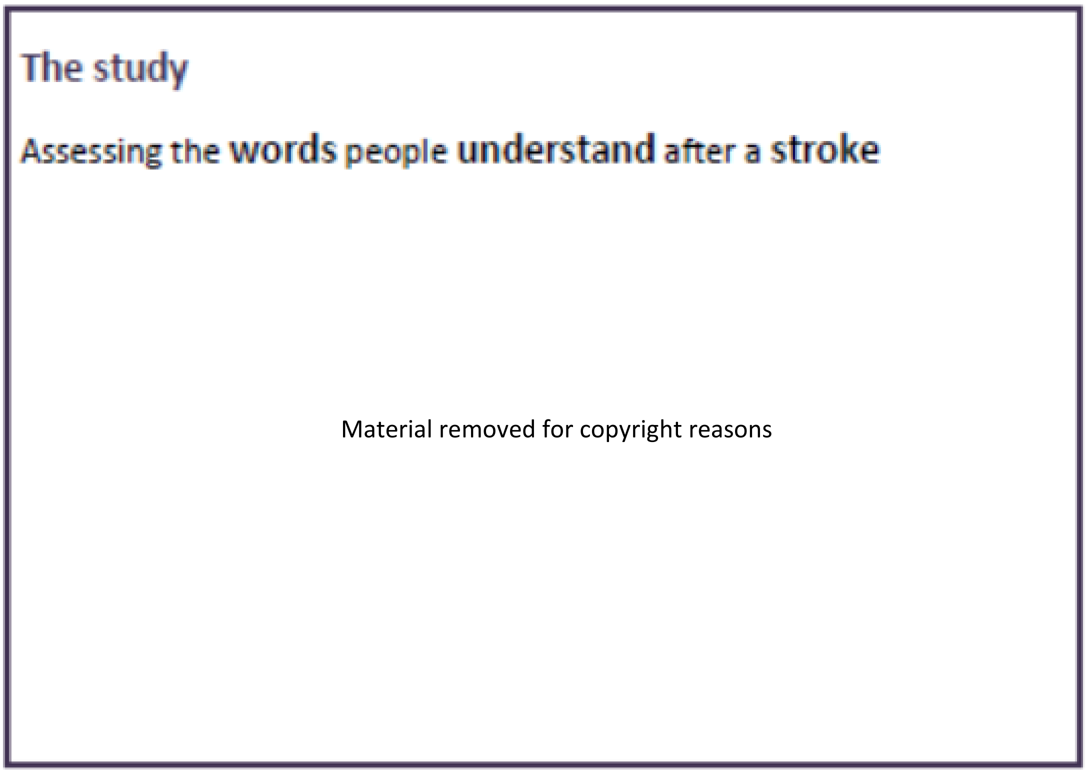
Material removed for copyright reasons

Supervisors:

Material removed for copyright reasons

Address:

Material removed for copyright reasons



The study

Assessing the **words** people **understand** after a **stroke**

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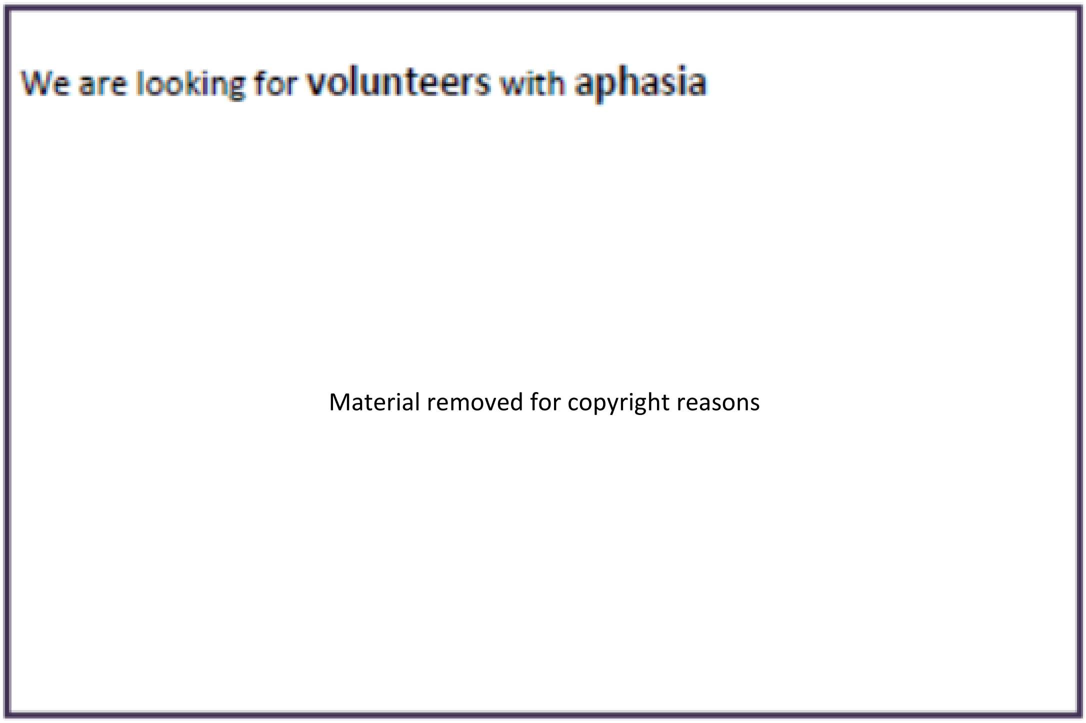

We are looking for **volunteers** with **aphasia**

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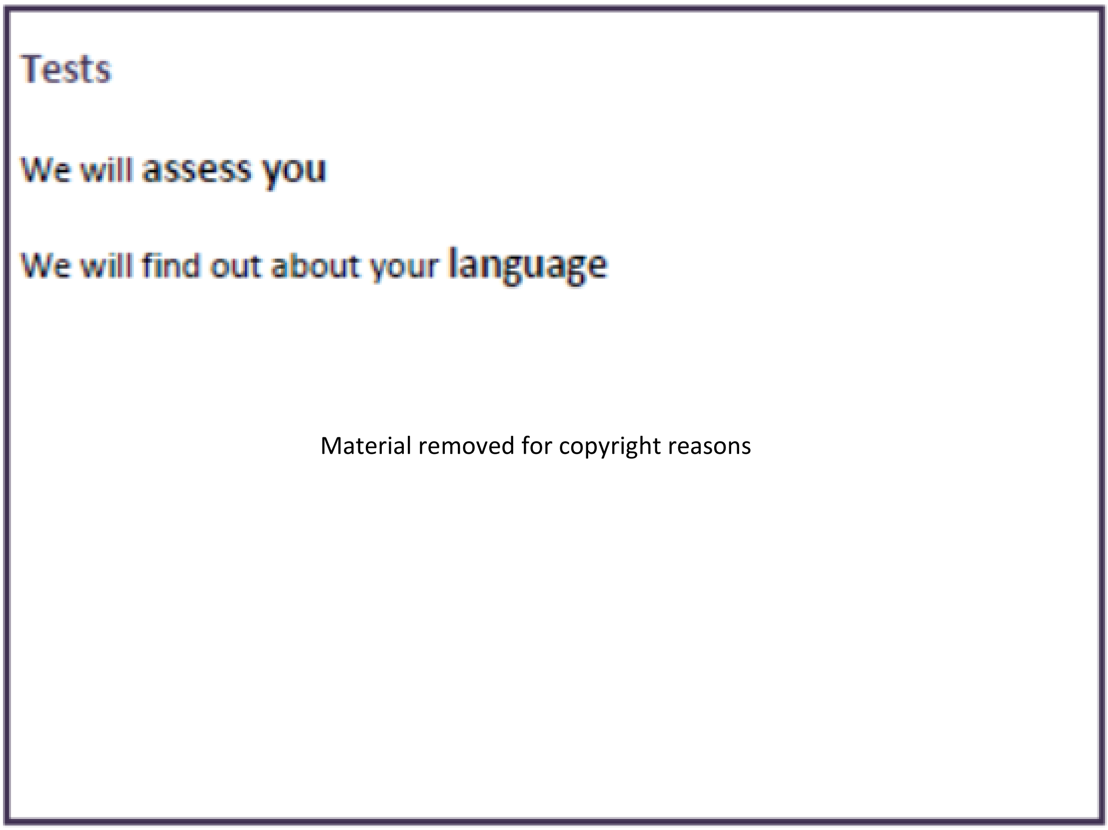
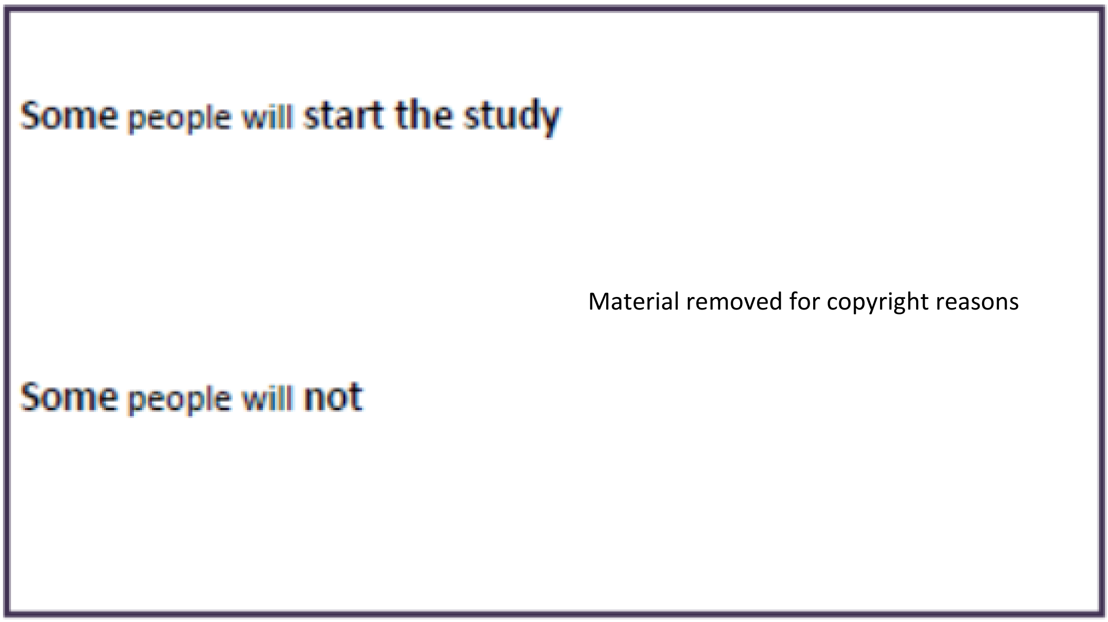


Tests

We will **assess you**

We will find out about your **language**

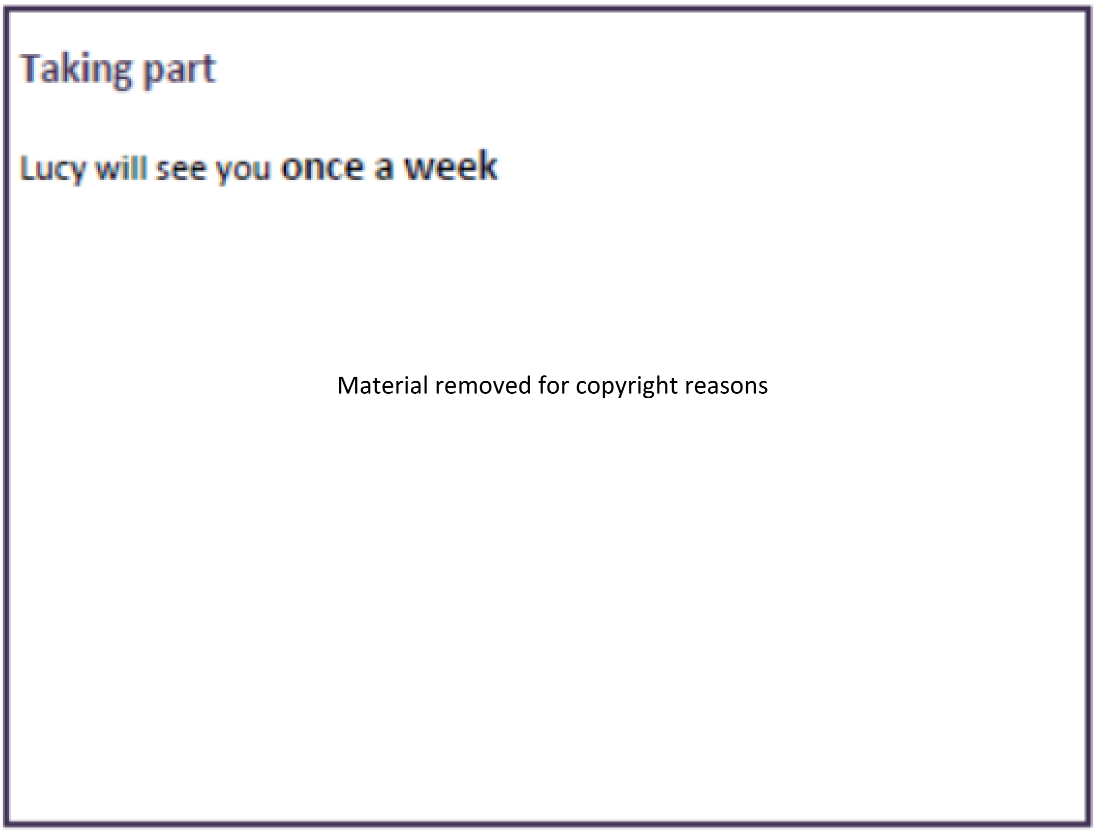
Material removed for copyright reasons



Some people will **start the study**

Material removed for copyright reasons

Some people will **not**



Taking part

Lucy will see you **once a week**

Material removed for copyright reasons

Taking part

Each session will last for **up to 2 hours**

Material removed for copyright reasons

Taking part

Taking part will last for **6 months maximum**

Material removed for copyright reasons

Taking part

Lucy can visit you at **home**

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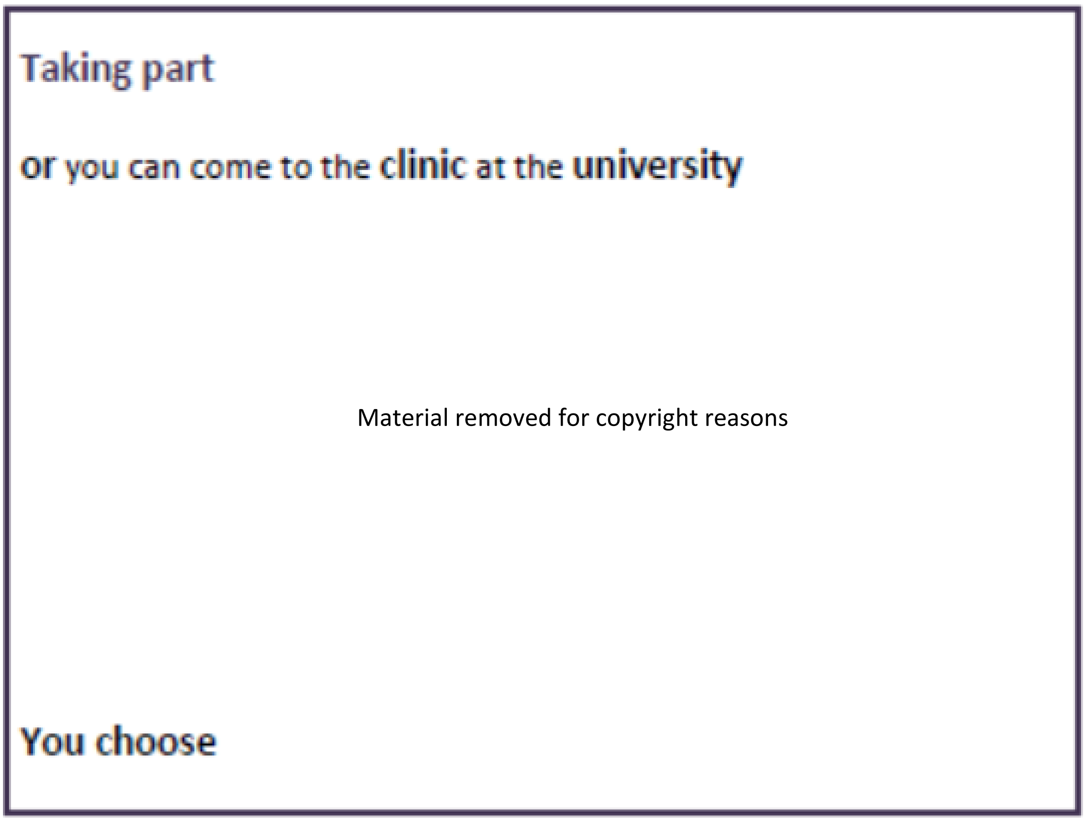
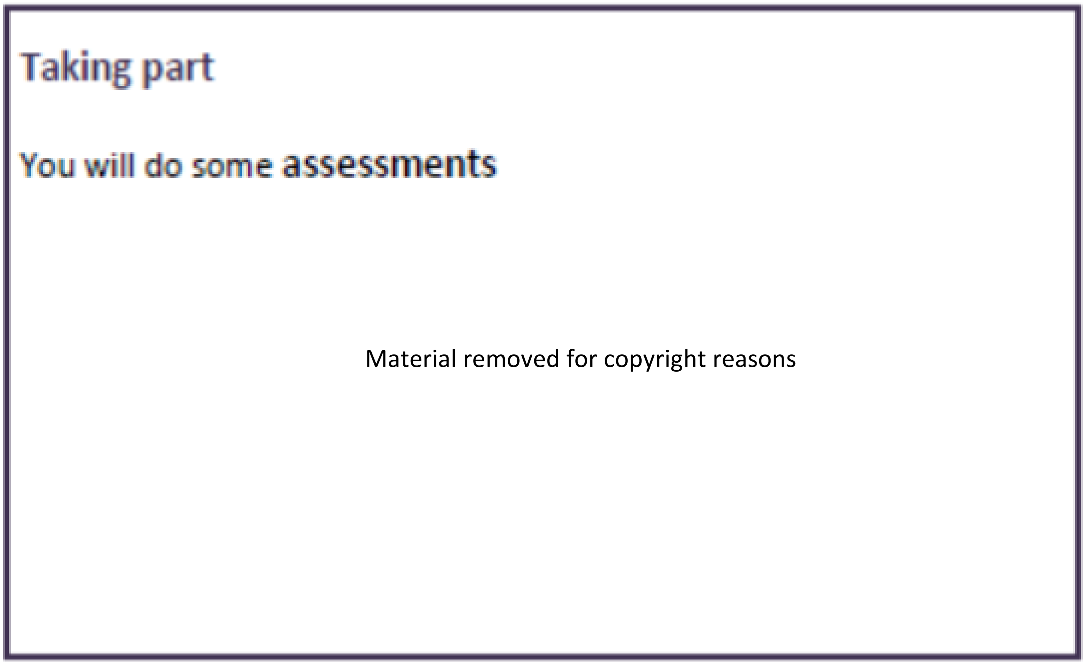


Taking part

or you can come to the **clinic** at the **university**

Material removed for copyright reasons

You choose



Taking part

You will do some **assessments**

Material removed for copyright reasons

Taking part

Some **assessments** are on a **computer**

Material removed for copyright reasons

Taking part is **not speech and language therapy**

Material removed for copyright reasons

You can **rest** at any **time**

Material removed for copyright reasons

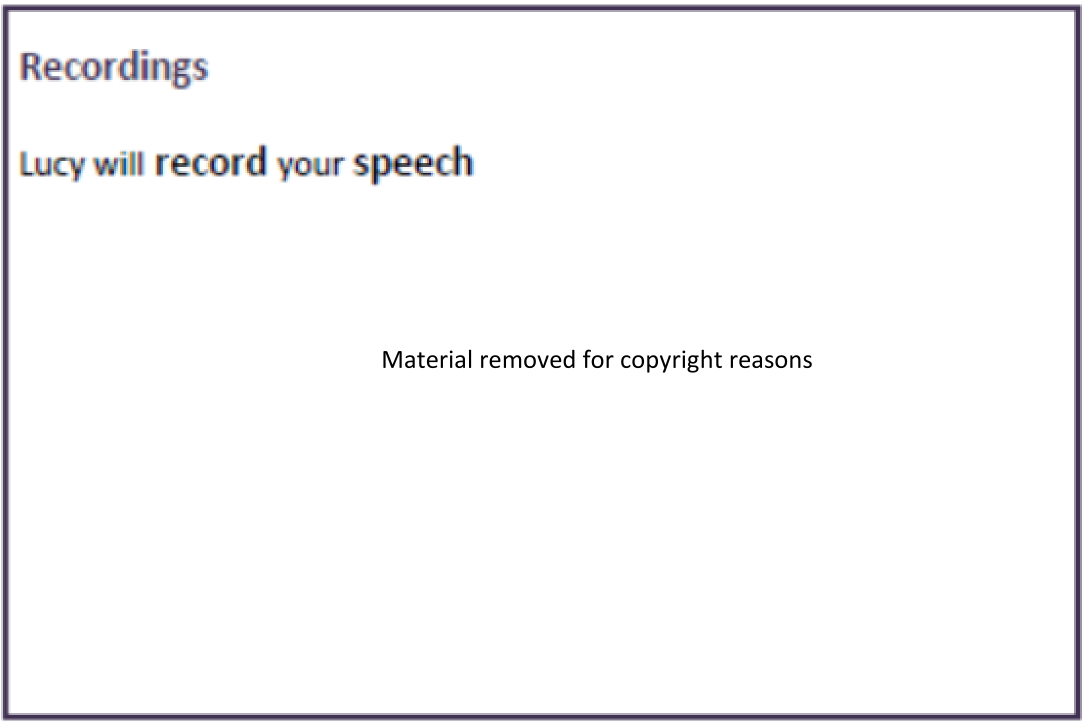
You can **stop** at **any time**

Material removed for copyright reasons

You do **not** need to give a **reason**

You can **still attend** your **communication group**

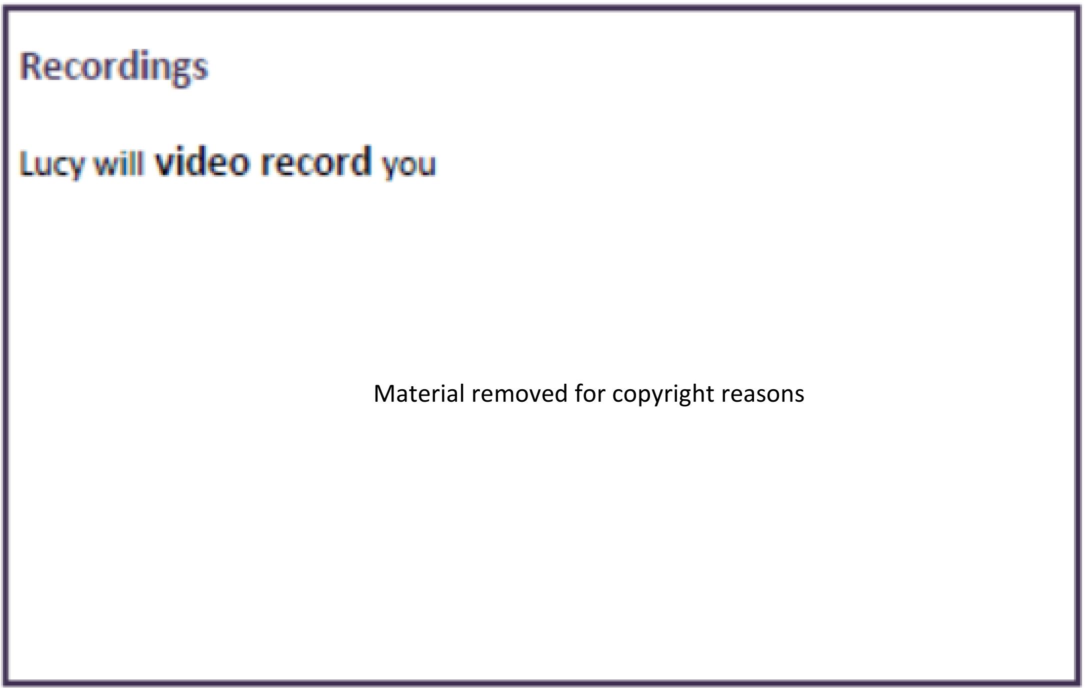
Material removed for copyright reasons



Recordings

Lucy will **record** your **speech**

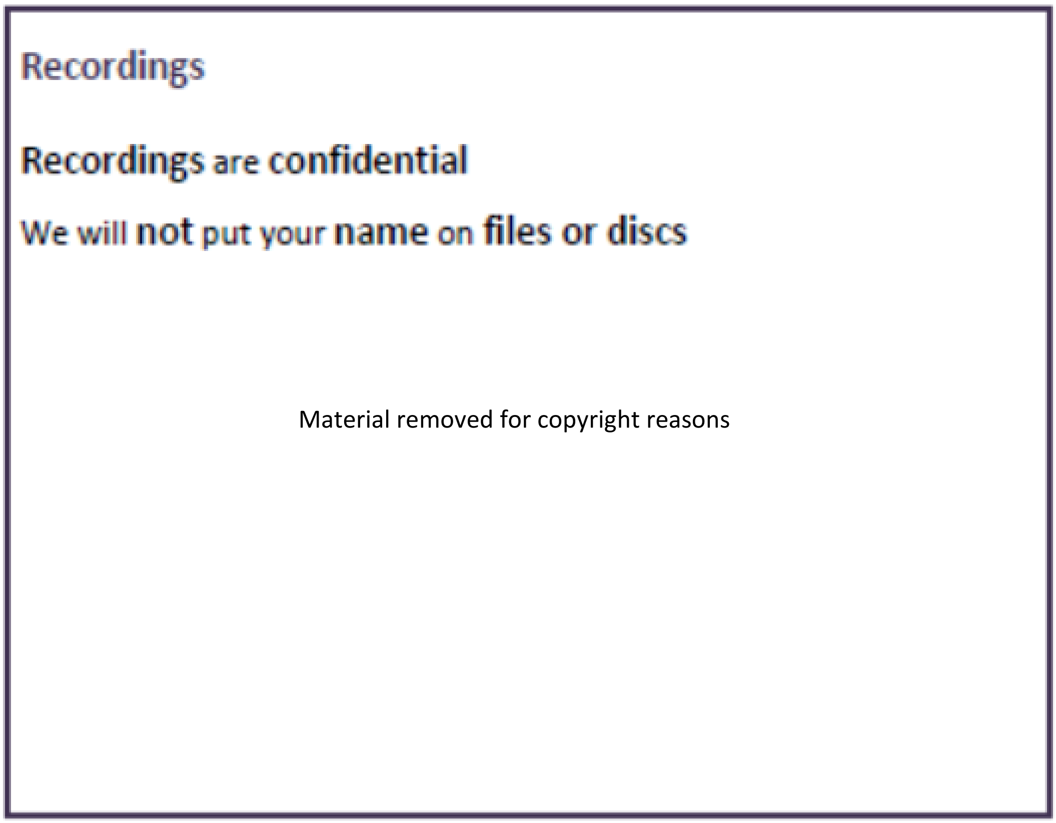
Material removed for copyright reasons



Recordings

Lucy will **video record** you

Material removed for copyright reasons



Recordings

Recordings are confidential

We will not put your name on files or discs

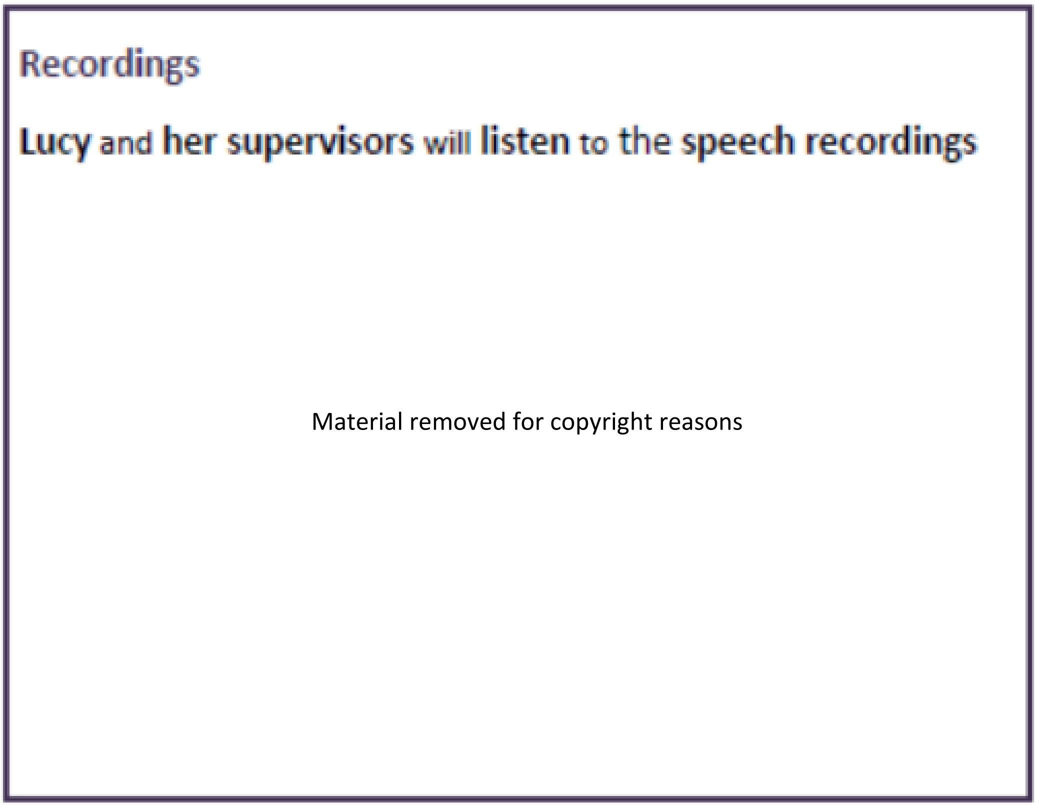
Material removed for copyright reasons

Recordings

We will keep recordings secure

We will lock recordings in an office

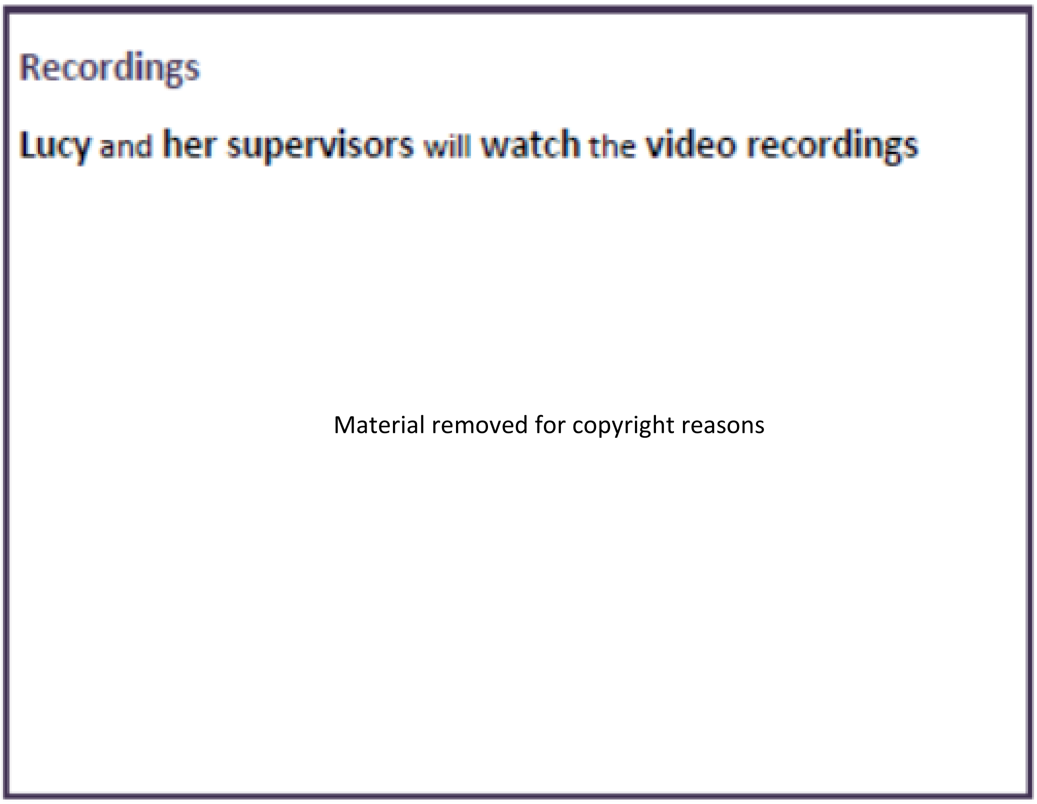
Material removed for copyright reasons



Recordings

Lucy and **her supervisors** will **listen** to **the speech recordings**

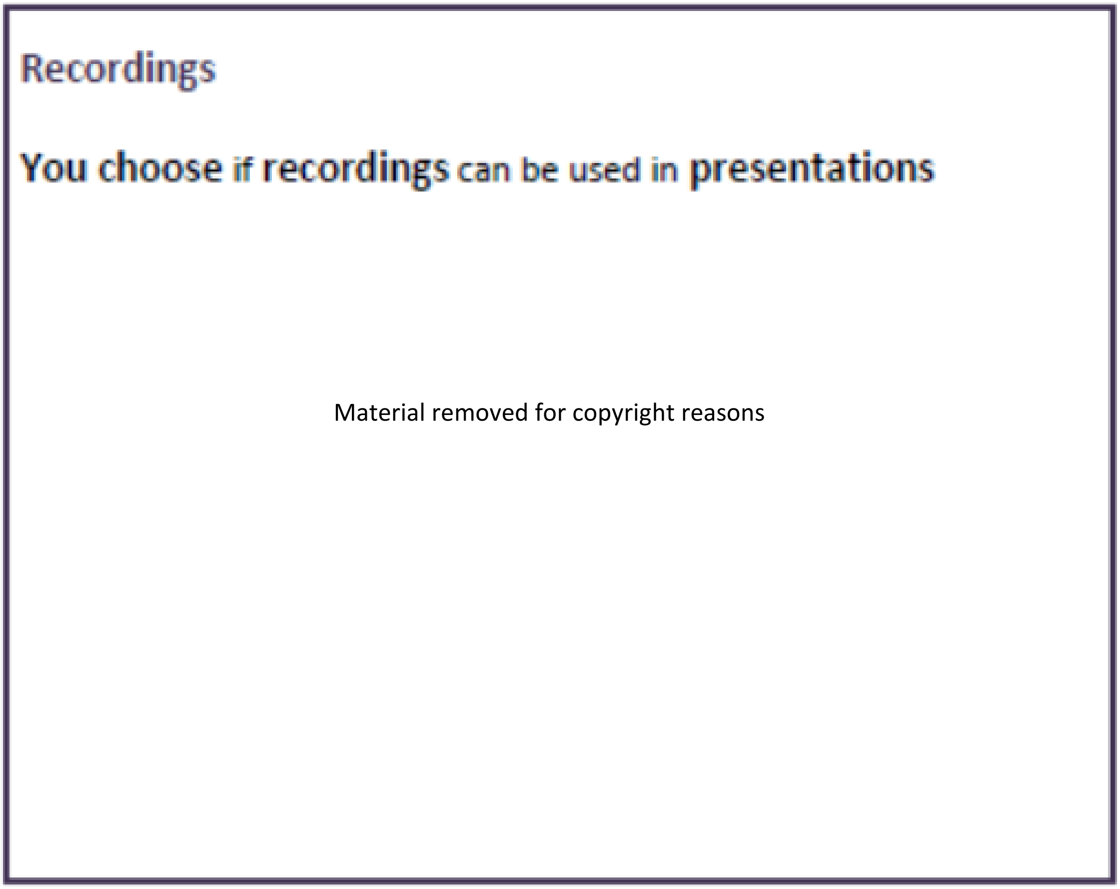
Material removed for copyright reasons



Recordings

Lucy and **her supervisors** will **watch** the **video recordings**

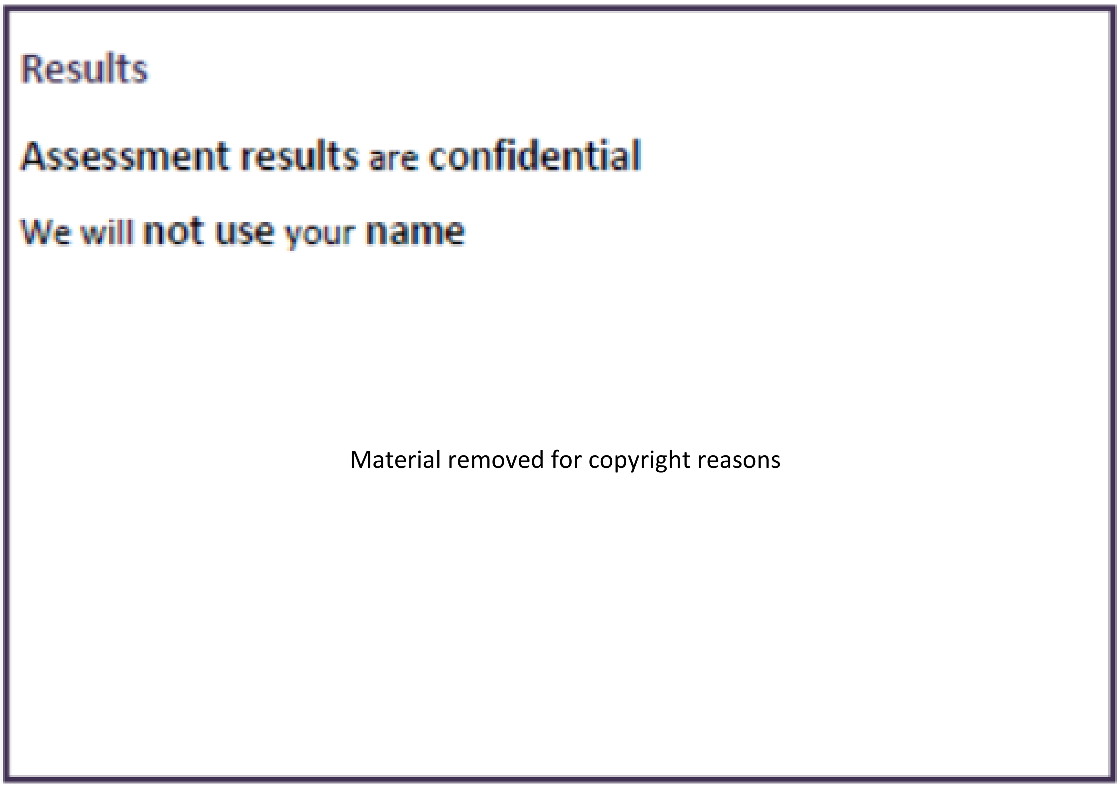
Material removed for copyright reasons



Recordings

You choose if **recordings** can be used in **presentations**

Material removed for copyright reasons

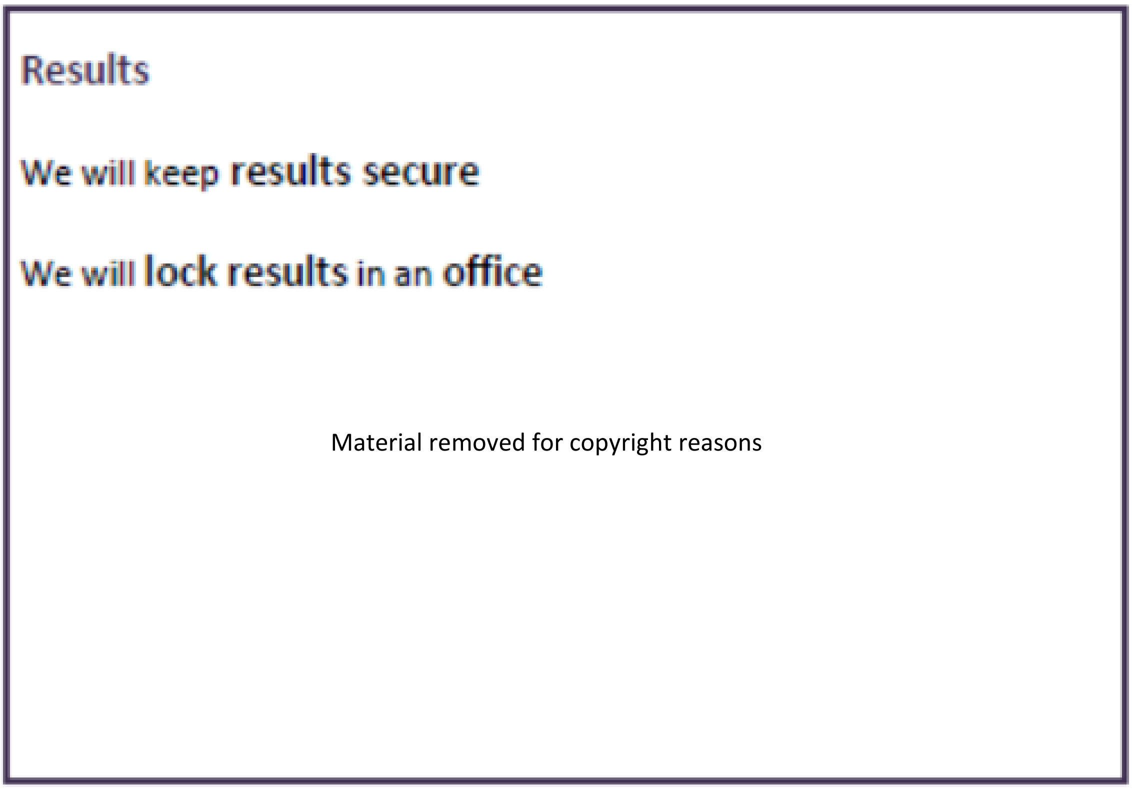


Results

Assessment results are **confidential**

We will **not use** your **name**

Material removed for copyright reasons

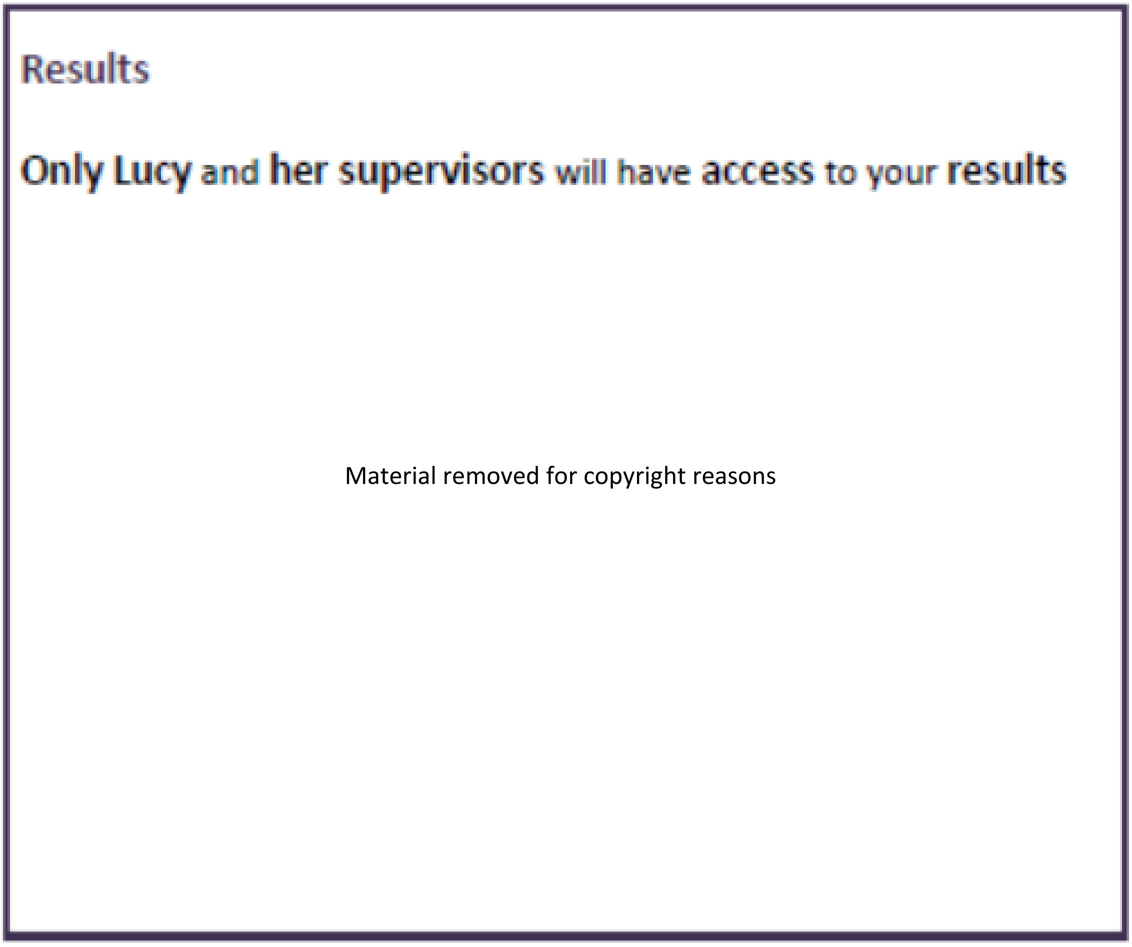


Results

We will keep results secure

We will lock results in an office

Material removed for copyright reasons



Results

Only Lucy and her supervisors will have access to your results

Material removed for copyright reasons

Results

We will write results in research reports

Material removed for copyright reasons

Results

Lucy will talk about the research at conferences

Material removed for copyright reasons

Results

Lucy will write **reports** and her **PhD**

Material removed for copyright reasons

Please tell if you **want** to **take part**

Material removed for copyright reasons

About the research

Any questions contact:

Lucy Dyson

Telephone:

email:

Material removed for copyright reasons

Concerns or complaints?

Head of Department

Material removed for copyright reasons

The
University
Of
Sheffield.

Material removed for confidentiality reasons

Consent Form

Language assessment for people with **aphasia**

Researcher: Lucy Dyson

The information sheet

	✓ x
1. The **information sheet** has been **explained**	☐
2. I **understand** the **information sheet**	☐
3. I have had the opportunity to ask **questions**	☐
4. I understand that I am **volunteering** to take part	☐
5. I understand that **I can stop** at **any time**	☐

Speech recordings

6. I understand that my **speech** will be **audio recorded** ☐

I agree to this

7. The **research team** will **listen to** the **speech recordings**

I agree to this ☐

8. **Speech recordings** may be used in **teaching** ☐

I agree to this

9. **Speech recordings** may be used in **public presentations**

I agree to this ☐

Video recordings

10. I will be **recorded** on **video**

I agree to this ☐

11. The **research team** will **see** the **video recordings**

I agree to this ☐

12. **Video recordings** may be used in **teaching**

I agree to this ☐

13. **Video recordings** may be used in **public presentations**

I agree to this ☐

Confidentiality

14. My **name** will **not be used** in the study or on the recordings

I understand this ☐

15. People could **recognise me** from my **recordings**

I understand this ☐

Future research

16. **My results** may be used in **future research**

I agree to this ☐

17. **My speech recordings** may be used in **future research**

I agree to this ☐

18. **My video recordings** may be used in **future research**

I agree to this ☐

19. **I agree** to **take part** in the research project ☐

Name of participant	Date	Signature
Name of researcher	Date	Signature

The University Of Sheffield.

Material removed for confidentiality reasons

Research project information sheet for family or carers

Testing understanding of word meaning in people with aphasia

This information sheet describes a research project at the University of Sheffield, looking at people's understanding of words after a stroke.

We are inviting people with aphasia to take part in the project. It is important for individuals to understand why the research is being done and what it will involve. It is also important for you to understand what taking part in the research will mean. Please ask if anything is unclear or if you would like more information.

What is the study about?
We are researching language understanding in people who have had a stroke. After having a stroke some people have aphasia, which means they can have difficulty understanding or producing spoken or written words and sentences. We will test people's understanding of words using a newly created computer test. We hope this will improve understanding about language comprehension difficulties after a stroke. This might then improve assessment methods and influence therapy choices in the future.

Who is taking part?
We are inviting individuals with language difficulties after a single stroke to take part. We are looking for people whose stroke happened a minimum of six months ago. If it is less than six months since they had the stroke then they cannot take part now. They will need to wait until they are six months post-stroke should they wish to take part.

Deciding whether to take part
Everyone is free to choose whether to take part in the study.

Attendance at any communication groups or any other care received will not be affected by choosing to take part or not.

Anyone who decides to take part will be given an information sheet and sign a consent form. Participants can withdraw from the study at any time and without giving a reason. If someone withdraws from the study, we will ask if they want the information already collected to be destroyed.

What will happen?
Lucy Dyson will visit participants at home or they can come to the Philippa Cottam Communication Clinic at the University of Sheffield. Lucy Dyson, is a qualified speech and language therapist and member of the Health and Care Professions Council.

People will complete a language screen to see if they are suitable to take part in the research. It may be that after the screen they do not take part in the project, and their involvements stops there. The screen is used to see if the research assessments are suitable for each individual.

If they progress onto the main project there will be approximately 6-8 assessment sessions each lasting up to 2 hours, over a 2-3 month period. 6 months after the first session there will be a one-off session in which one test is repeated. Participants will do a number of standard speech and language tests tests for example naming pictures, listening to words and sentences, and repeating words. Participants will also complete tests on a laptop computer which involve looking at pictures and reading words.

During assessments speech will be audio-recorded. Some speech may also be video recorded should the participant consent to this. The audio and video recordings will allow us to describe people's speech and language in more detail.

What will happen to the data and recordings?
The researcher, Lucy Dyson, will securely keep all data, audio and video recordings on her password-protected computer at the University of Sheffield. Paper-based information will be kept securely in a locked filing cabinet.

Research data will be used in analysis, reports and presentations. Audio and video recordings will be used for analysis purposes within the project team, and may be used in teaching or research presentations should the participant give their permission. No other use will be made of electronic data or recordings without participants' written permission, and no one outside the project will be allowed access to original recordings. The participant can choose if their data and recordings can be used in future research or not. If they choose for data and recordings not to be used in future research then they will be destroyed at the end of the study.

Data will be anonymised: names will not be used in any test data collected, instead people will be assigned with a code name. Data will be used in research publications, but participants will not be identifiable as names or personal information will not be used. If a participant consents to audio and video recordings being used for educational purposes or in research presentations, there is the possibility that they could be identified by people listening to or viewing the recordings, however their name will not be used.

What will happen to the results of the study?
The results will be used as part of Lucy Dyson's PhD thesis and will be reported at conferences and in written reports in the future. The results may also be presented to local groups and organisations supporting people with aphasia. In any report of the study, we will ensure that participants cannot be identified by their name. As discussed above however, anonymity cannot be guaranteed if the participant consents to use of their audio or video footage in research presentations.

Will taking part be kept confidential?
Yes. All information will be confidential. Participants' names, and other personal details will not be revealed to any person outside the project.

What are the potential disadvantages and risks of taking part?
There are unlikely to be specific risks or disadvantages to taking part. Sessions will involve language assessments typically administered in rehabilitation settings. Some other tests will involve doing a simple computer task. Participants may become frustrated if they are unfamiliar with using a computer. However, we will provide training, practise and support to minimise the risk of this occurring. Participants may become fatigued during assessment sessions, but sessions will be kept to a manageable length, with regular breaks. Participants can request breaks or can stop at any time should they wish.

What are the potential benefits of taking part?
It is unlikely that taking part in the study will have direct benefit to participants. It does provide the opportunity however to take part in a research project, the results of which will teach us more about language comprehension after stroke and may help other people with aphasia in the future.

Who is funding the research?
The project is funded by the Stroke Association.

Ethical approval
This study is approved by the Department of Human Communication Sciences Research Ethics Review Panel.

Research Team
Lucy Dyson is a PhD student in the Department of Human Communication Sciences at The University of Sheffield. Dr Ruth Herbert and Dr Richard Body are senior lecturers supervising Lucy's PhD. All team members are qualified speech and language therapists registered with the Health and Care Professions Council.

Researcher: Lucy Dyson

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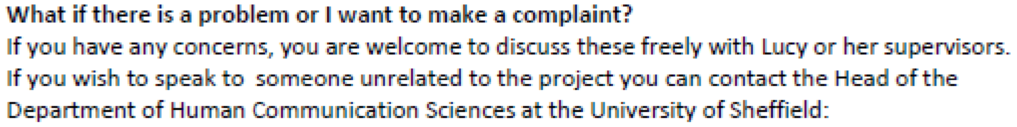
Supervisors: Dr Ruth Herbert

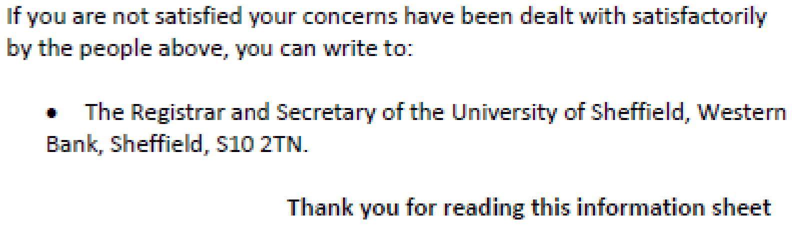
Dr Richard Body

Further information
For further information please contact the researcher, Lucy Dyson.



What if there is a problem or I want to make a complaint?
If you have any concerns, you are welcome to discuss these freely with Lucy or her supervisors. If you wish to speak to someone unrelated to the project you can contact the Head of the Department of Human Communication Sciences at the University of Sheffield:

Material removed for confidentiality reasons



If you are not satisfied your concerns have been dealt with satisfactorily by the people above, you can write to:

- The Registrar and Secretary of the University of Sheffield, Western Bank, Sheffield, S10 2TN.

Thank you for reading this information sheet

Appendix K: Control participant demographics

Participant	Age	Sex	Years in education	Handedness
1	63	F	12	R
2	65	M	16	R
3	54	F	18	L
4	63	M	17	R
5	54	M	15	R
6	43	F	18	R
7	41	M	18	R
8	67	F	11	R
9	67	M	10	R
10	44	M	18	R
11	57	F	12	R
12	66	M	11	L
13	68	F	10	R
14	58	M	10	R
15	61	F	16	R
16	61	M	16	R
17	65	M	18	R
18	63	F	13	R
19	73	F	16	R
20	70	M	17	R
21	65	F	16	R
22	70	F	12	L
23	65	F	15	R
24	68	M	18	L
25	81	F	11	R
26	58	F	16	R
27	66	F	16	R
28	68	M	18	R
29	66	F	13	R
30	46	F	12	R
31	69	F	10	R
32	56	F	15	R
33	64	M	12	R
34	71	M	18	R
35	64	F	16	R
36	64	M	16	L
37	67	M	16	L
38	62	F	16	R
39	66	F	11	R
40	68	F	10	R

Appendix L: PWA timeframe of testing

Number of testing sessions and time between times 1 and 2 presentation of SP and WPV tasks for PWA.

Participant	Number of testing sessions	Time between semantic priming 1 and 2 (days)	Time between word to picture verification 1 and 2 (days)
BT	8	185	57
CW	7	189	70
DB	5	185	96
DH	7	186	50
DW	6	186	49
FM	7	185	83
GB	7	186	61
JC	6	189	71
JK	5	182	25
JM	8	198	84
LW	5	193	64
NMH	7	186	71
PG	6	189	84
PS	7	183	84
RP	8	188	63
RT	7	184	63
SE	7	189	49
SH	7	183	68
SL	7	185	44
TS	7	200	84

Appendix M: Matching of word lists between tasks

Table M1: Mean ratings for psycholinguistic variables of word lists in the SP task

	List 1 primes	List 2 primes	List 1 targets	List 2 targets
BNC written frequency	17.04 (21.40)	26.16 (55.16)	20.95 (19.75)	24.29 (38.55)
Imageability	595 (41.77)	577 (36.05)	595 (21.07)	591 (24.72)

Note. Standard deviation in brackets.

Table M2: Mean ratings for psycholinguistic variables of word lists in the WPV task

	List 1 distractors	List 2 distractors	List 1 targets	List 2 targets
BNC written frequency	20.38 (38.30)	23.23 (33.13)	20.43 (30.42)	19.93 (20.07)
Imageability	578 (39.49)	583 (37.35)	598 (20.47)	595 (19.72)

Note. Standard deviation in brackets.

Appendix N: Tests of normality

Table N1: Semantic Priming normality tests for target response latency in the related condition

	Kolmogorov-Smirnov	***p***	**Skewness**	**Standard error**	***z***	**Kurtosis**	**Standard error**	***z***
Control group participant level	.09	.200	-.01	.37	-.02	-.39	.73	-0.53
Control group item level	.08	.200	.20	.34	.58	-.20	.66	-0.30
PWA group participant level time 1	.23	.009*	1.46	.51	2.85*	2.98	.99	3.01*
PWA group item level time 1	.11	.154	1.35	.34	4.00*	2.79	.66	4.22*
BT	.16	.004*	1.28	.34	3.79*	1.73	.66	2.61*
CW	.21	.000***	1.78	.34	5.23*	3.64	.67	5.46*
DB	.18	.001**	.93	.34	2.72*	-.11	.67	-.16
DH	.23	.000***	1.84	.37	4.91*	3.32	.73	4.53*
DW	.20	.000***	1.20	.37	3.25*	1.43	.72	1.98*
FM	.16	.021*	.87	.40	2.19*	1.35	.78	1.73
GB	.16	.021*	.90	.37	2.43*	.70	.72	.97
JC	.13	.060	.64	.36	1.77	2.39	.71	3.38*
JK	.18	.000***	.95	.22	4.23*	.77	.44	1.74
JM	.22	.000***	2.43	.35	7.01*	6.97	.68	10.24*
LW	.18	.000***	.88	.34	2.62*	.40	.66	.60
NMH	.15	.006*	.88	.34	2.57*	.64	.67	.96
PG	.17	.001**	1.74	.35	5.01*	4.61	.68	6.77*
PS	.20	.000***	1.57	.36	4.36*	2.52	.71	3.55*
RP	.17	.002*	2.10	.34	6.16*	5.58	.67	8.35*
RT	.12	.074	.63	.35	1.79	1.51	.69	2.20*
SE	.16	.003*	1.20	.34	3.54*	1.09	.67	1.64
SH	.11	.190	.58	.34	1.70	.17	.67	.26
SL	.15	.006*	.79	.34	2.31*	-.33	.67	-.49
TS	.24	.000**	1.41	.35	4.06*	.80	.68	1.17

Note. *p* = significance level; *z* = effect size significant as highlighted by * if value greater than 1.96. ***p ≤ .001; **p ≤ .01; *p ≤ .05.

Table N2: Semantic Priming normality tests for target response latency in the unrelated condition

	Kolmogorov-Smirnov	***p***	**Skewness**	**Standard error**	***z***	**Kurtosis**	**Standard error**	***z***
Control group participant level	.10	.200	.04	.37	.10	-.55	.73	-.74
Control group item level	.08	.200	.23	.34	.69	.20	.66	.31
PWA group participant level time 1	.19	.060	1.44	.51	2.81*	3.15	.99	3.18*
PWA group item level time 1	.12	.073	.61	.34	1.82	-.03	.66	-.05
BT	.22	.000***	1.49	.34	4.43*	1.33	.66	2.01*
CW	.19	.000***	1.05	.34	3.10*	.48	.67	.71
DB	.14	.021	.53	.34	1.53	-.75	.67	-1.12
DH	.17	.007*	1.10	.37	2.95*	.55	.73	.75
DW	.20	.000***	.88	.37	2.39*	.43	.72	.59
FM	.16	.021*	2.17	.40	5.46*	6.84	.78	8.79*
GB	.19	.001**	.80	.37	2.15*	-.40	.72	-.55
JC	.11	.200	.80	.36	2.20*	1.31	.71	1.85
JK	.17	.000***	3.54	.22	15.79*	3.54	.22	15.79*
JM	.16	.003*	1.22	.35	3.52*	1.28	.68	1.87
LW	.21	.000***	1.70	.34	5.05*	3.50	.66	5.29*
NMH	.14	.019	.29	.34	.86	-.04	.67	-.07
PG	.26	.000***	1.93	.35	5.55*	3.27	.68	4.80*
PS	.19	.001**	1.37	.36	3.80*	2.37	.71	3.34*
RP	.12	.075	1.49	.34	4.39*	3.10	.67	4.63*
RT	.18	.001**	1.20	.35	3.44*	2.67	.69	3.88*
SE	.14	.013*	1.10	.34	3.22*	.98	.67	1.47
SH	.15	.008*	.88	.34	2.59*	.88	.67	1.32
SL	.17	.001**	.86	.34	2.52*	.03	.67	.05
TS	.20	.000***	1.20	.35	3.46*	.89	.68	1.31

Key: *p* = significance level; *z* = effect size significant as highlighted by * if value greater than 1.96. *p*: ***p ≤ .001; **p ≤ .01; *p ≤ .05.

Table N3: Word to Picture Verification normality tests for target accuracy

	Kolmogorov-Smirnov	***p***	**Skewness**	**Standard error**	***z***	**Kurtosis**	**Standard error**	***z***
Participant level								
Control group: congruent condition	.43	.000***	-1.324	.374	-3.54*	.856	.733	1.17
PWA group: congruent condition	.20	.045	-.77	.51	-1.51	-.07	.99	-.07
Control group: incongruent condition	.19	.001**	-1.28	.37	-3.42*	4.18	.73	5.7*
PWA group: incongruent condition	.17	.119	-.86	.51	-1.68	.47	.99	.47
Item level								
Control group: congruent condition	.30	.000***	-.06	.34	-.16	-1.81	.66	-2.7*
PWA group: congruent condition	.35	.000***	-2.13	.34	-6.31*	5.43	.66	8.0*
Control group: incongruent condition	.26	.000***	-1.79	.34	-5.32*	3.04	.66	-1.79
PWA group: incongruent condition	.16	.003*	-.91	.34	-2.70	-.13	.66	-.91

Note. z = effect size significant as highlighted by * if value greater than 1.96; *p*: ***p ≤ .001; *p ≤ .05.

Table N4: Word to Picture Verification normality tests for target response latency

	Kolmogorov-Smirnov	***p***	**Skewness**	**Standard error**	***z***	**Kurtosis**	**Standard error**	***z***
Congruent condition								
Control group: participant level	.11	-.17	.37	-.44	-1.22	.73	-1.66	-.17
PWA group: participant level	.25	2.12	.51	4.15	5.64*	.99	5.69	2.12*
Control group: item level	.12	.051*	.56	.34	1.67	-.22	.66	-.34
PWA group: item level	.13	.038*	1.00	.34	2.96*	.82	.66	1.24
Incongruent condition								
Control group: participant level	.11	.200	.29	.37	.77	.55	.73	.75
PWA group: participant level	.20	.036*	1.56	.51	3.05*	2.82	.99	2.84*
Control group: item level	.14	.021*	.71	.34	2.11*	.12	.66	.19
PWA group: item level	.13	.026*	.95	.34	2.82*	.52	.66	.78

Note. *p* = significance level; *z* = effect size significant as highlighted by * if value greater than 1.96. *p ≤ .05.

Table N5: Word to Picture Matching normality tests for target accuracy

	Kolmogorov-Smirnov	***p***	**Skewness**	**Standard error**	***z***	**Kurtosis**	**Standard error**	***z***
Participant level								
Control group	.37	.000***	-1.55	.37	-4.15*	1.76	.73	2.40*
PWA group	.26	.001**	-2.57	.51	-5.02*	8.50	.99	8.56*
Item level								
Control group	.39	.000***	-2.59	.34	-7.68*	6.87	.66	10.38*
PWA group	.25	.000***	-1.26	.34	-3.75*	1.15	.66	1.74

Note z = effect size significant as highlighted by * if value greater than 1.96; ***p ≤ .001; **p ≤ .01.

Table N6: Word to Picture Matching normality tests for target response latency

	Kolmogorov-Smirnov	***p***	**Skewness**	**Standard error**	***Z***	**Kurtosis**	**Standard error**	***Z***
Participant level								
Control group	.09	.200	.23	.37	0.60	-.37	.73	-.50
PWA group	.21	.022*	1.57	.51	3.06*	2.76	.99	2.78*
Item level								
Control group	.10	.200	.46	.34	1.36	-.38	.66	-.58
PWA group	.12	.076	1.39	.34	4.12*	3.73	.66	5.63*

Note. p = significance level; *z* = effect size significant as highlighted by * if value greater than 1.96. *p ≤ .05.

Appendix O: Semantic priming parametric test results for PWA

Table O1: PWA semantic priming mixed ANOVA results: effect of relatedness, relationship and interaction between relatedness and relationship

PWA	**Main effect of relatedness condition**					**Main effect of stimuli relationship**						**Interaction**		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Difference overall (unrelated - related)	*F*	*df*	*p*	Partial Eta squ	RT to primed and unprimed semantically similar targets (ms)	RT to primed and unprimed associated targets (ms)	Relationship effect (ms)[a]	*F*	*p*	Partial Eta squ	*F*	*p*	Partial Eta squ
BT	56	.722	1,48	.400	.015	1226 (315)	1237 (279)	11	.023	.880	.000	.918	.343	.019
CW	26	.273	1,47	.603	.006	915 (160)	941 (192)	26	.475	.494	.010	.658	.421	.014
DB	3	.064	1,46	.801	.001	910 (197)	889 (185)	-21	.188	.667	.004	1.445	.236	.030
DH	182	6.054	1,38	.019*	.137	1496 (534)	1403 (420)	-93	.492	.487	.013	2.063	.159	.051
DW	15	.000	1,39	.989	.000	1051 (194)	1043 (236)	-8	.021	.887	.001	1.383	.247	.034
FM	63	.103	1,33	.751	.003	1787 (525)	1838 (456)	51	.154	.697	.005	.343	.562	.010
GB	110	6.120	1,39	.018*	.136	1162 (259)	1072 (173)	-90	2.375	.131	.057	.394	.534	.010
JC	32	.576	1,41	.452	.014	1376 (205)	1338 (120)	-38	.776	.383	.019	.226	.637	.005
JK	45	1.633	1,47	.207	.034	1217 (150)	1271 (353)	54	.966	.331	.020	1.066	.307	.022

PWA	Main effect of relatedness condition					Main effect of stimuli relationship						Interaction		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Difference overall (unrelated - related)	*F*	*df*	*p*	Partial Eta squ	RT to primed and unprimed semantically similar targets (ms)	RT to primed and unprimed associated targets (ms)	Relationship effect (ms)[a]	*F*	*p*	Partial Eta squ	*F*	*p*	Partial Eta squ
JM	126	.209	1,45	.650	.005	2166 (773)	2330 (1092)	164	.835	.366	.018	.194	.661	.004
LW	96	6.175	1,48	.016*	.114	1014 (211)	1000 (161)	-14	.099	.754	.002	.344	.560	.007
NMH	-5	.516	1,47	.476	.011	1002 (114)	1030 (120)	28	1.252	.269	.026	2.848	.098	.057
PG	10	.000	1,45	.998	.000	1598 (540)	1531 (429)	-67	.406	.527	.009	.075	.786	.002
PS	7	.170	1,41	.682	.004	1367 (285)	1380 (281)	13	.041	.841	.001	2.971	.092	.068
RP	33	.202	1,47	.655	.004	1156 (363)	1107 (262)	-49	.700	.407	.015	.025	.875	.001
RT	30	.033	1,44	.856	.001	1344 (289)	1337 (213)	-7	.017	.897	.000	1.190	.281	.026
SH	55	2.989	1,47	.090	.06	1210 (192.45)	1201 (197)	-9	.046	.832	.001	1.270	.266	.026
SL	55	2.913	1,46	.095	.06	1302 (207)	1301 (235)	-1	.001	.980	.000	1.525	.223	.032
SE	6	.002	1,47	.962	.000	1387 (304)	1322 (270)	-65	.922	.342	.019	.383	.539	.008
TS	180	6.622	1,45	.013*	.128	1391 (499)	1344 (433)	-47	.151	.699	.003	1.003	.322	.022

Note. Standard deviation in brackets. Negative values indicate faster response latencies to targets in the associated category compared to targets in the semantically similar category, positive values indicate faster response latencies to targets in the semantically similar category.

***p ≤ .001; **p ≤ .01; *p ≤ .05.

Table O2: Response latency (ms) to targets at testing time 1 and 2 for PWA

PWA	**Total targets at each time of testing**	**Time 1 all targets**	**Time 2 all targets**	**Difference from time 1 to time 2**[a]	***t***	***df***	***p* (2-tailed)**
BT	50	1248 (319)	1213 (284)	-35	.717	49	.477
CW	49	971 (195)	878 (130)	-93	2.973	48	.005**
DB	48	914 (193)	891 (194)	-23	.717	47	.477
DH	40	1411 (506)	1508 (477)	97	-1.123	39	.268
DW	41	1041 (189)	1055 (228)	14	-.335	40	.739
FM	35	1983 (578)	1625 (326)	-358	3.514	34	.001***
GB	41	1137 (222)	1117 (244)	-20	.413	40	.682
JC	43	1394 (196)	1330 (154)	-64	1.889	42	.066
JK	49	1251 (171)	1220 (295)	-31	.668	48	.507
JM	47	2669 (999)	1775 (449)	-894	6.003	46	.000***
LW	50	1014 (224)	1004 (159)	-10	.234	49	.816

PWA	**Total targets at each time of testing**	**Time 1 all targets**	**Time 2 all targets**	**Difference from time 1 to time 2[a]**	***t***	***df***	***p* (2-tailed)**
NMH	49	1038 (107)	986 (120)	-52	2.290	48	.026*
PG	47	1364 (375)	1787 (530)	432	-4.712	46	.000***
PS	43	1377 (273)	1365 (294)	-12	.198	42	.844
RP	49	1350 (332)	928 (140)	-422	8.877	48	.000***
RT	46	1396 (140)	1288 (340)	-108	2.032	45	.048*
SE	49	1480 (298)	1246 (237)	-234	5.943	48	.000***
SH	49	1136 (165)	1276 (195)	140	-4.252	48	.000***
SL	48	1346 (195)	1256 (229)	-90	2.223	47	.031*
TS	47	1402 (421)	1346 (525)	-56	.711	46	.481

Note. Highlighted rows indicate the PWA with a main effect of relatedness condition. Standard deviation in brackets. Negative values indicate quicker response latencies to targets at time two, positive values indicate slower response latencies to targets at time two.

p ≤ .001; **p ≤ .01; *p ≤ .05.

Appendix P: Individual PWA WPV results

Table P1: Effect of congruence condition on individual PWA accuracy

	Congruent and incongruent accuracy							**Effect of incongruent target-distractor relationship type**						
PWA	Accurate in both conditions	Errors in both conditions	Accurate congruent only	Accurate incongruent only	Cong accuracy (50)	Incongruent accuracy (50)	McNemar *p* value (2-tailed)	Accurate in semantically similar condition (32)	Accurate in associated condition (18)	Total (*n*)	*df*	χ^2	Fisher's exact test *p*	*phi*
BT	45	0	3	2	48	47	1.000	31	16	50	1	.27	.291	-.161
CW	43	0	5	2	48	45	.453	27	18	50	1	1.63	.145	.250
DB	43	0	7	0	50	43	.016*	27	16	50	1	.000	1.000	.062
DH	31	1	14	4	45	35	.031*	24	11	50	1	.500	.348	-.145
DW	41	0	5	4	46	45	1.000	28	17	50	1	.087	.642	.111
FM	31	0	15	4	46	35	.019*	23	12	50	1	.004	.754	-.055
GB	36	0	14	0	50	36	.000*	23	13	50	1	.000	1.000	.004
JC	24	0	26	0	50	24	.000*	18	6	50	1	1.593	.149	-.220
JK	33	0	15	2	48	35	.002*	24	11	50	1	.500	.348	-.145
JM	30	0	20	0	50	30	.000*	22	8	50	1	1.913	.134	-.238
LW	41	0	9	0	50	41	.004*	26	15	50	1	.000	1.000	.026
NMH	41	0	8	1	49	42	.039*	27	15	50	1	.000	1.000	-.014
RP	41	0	8	1	49	42	.039*	26	16	50	1	.093	.694	.100
RT	37	1	11	1	48	38	.006*	26	12	50	1	.663	.309	-.164
PG	47	0	3	0	50	47	.250	31	16	50	1	.271	.291	-.161
PS	23	1	26	0	49	23	.000*	14	9	50	1	.017	.771	.060
SE	38	0	11	1	49	39	.006*	26	13	50	1	.148	.494	-.105
SH	41	1	7	1	48	42	.070	29	13	50	1	1.695	.118	-.241
SL	34	0	14	2	48	36	.004*	25	11	50	1	.918	.325	-.182
TS	35	1	12	2	47	37	.013*	22	15	50	1	.628	.328	.160

Appendix Q: Individual PWA WPM results

Individual PWA response latency, accuracy and error patterns in the WPM task

PWA	Response latency (ms)	Accuracy (50)	Overall semantic errors	Semantically similar errors	Associated errors	Phonological errors	Unrelated errors
BT	3492 (1109)	49	1	1	0	0	0
CW	2248 (926)	49	1	1	0	0	0
DB	2361 (688)	49	1	1	0	0	0
DH	10161 (5070)	47	3	2	1	0	0
DW	3194 (1164)	47	1	1	0	2	0
FM	5554 (1996)	47	2	2	0	1	0
GB	2823 (981)	49	0	0	0	0	1
JC	4485 (1679)	46	3	3	0	1	0
JK	3805 (1327)	46	3	3	0	1	0
JM	6959 (3241)	44	5	4	1	1	0
LW	2613 (1210)	48	2	2	0	0	0
NMH	3491 (1568)	48	2	2	0	0	0
PG	5913 (1499)	50	0	0	0	0	0
PS	3425 (1794)	36	9	6	3	3	2
RP	3020 (1192)	48	2	2	0	0	0
RT	5453 (3139)	47	3	3	0	0	0
SE	3938 (1602)	48	0	0	0	1	1
SH	6829 (3466)	50	0	0	0	0	0
SL	2962 (952)	44	5	5	0	1	0
TS	4047 (2244)	47	3	3	0	0	0

Note. Standard deviation in brackets.