Remembering out-of-context:

A developmental perspective

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Abstract

Contextual influences on memory retrieval are of theoretical and empirical importance in infant memory research. Early in infancy, memory is strongly constrained by contextual congruency at encoding and retrieval. Contextual constraints appear to progressively loosen over the infancy period (Hayne, 2004), but little is known about the nature and extent of this change.

The present studies revealed that age-related decreases in contextual constraints on memory retrieval extend to both physical and social context, and to recall and recognition memory (Experiments 1-4). Specifically, for 9-month-olds both recognition and recall memory were less affected by a change of social context than for 6-month-olds, and for 12-month-olds, recognition memory was less influenced by a change of global physical context than for 6-month-olds. At 12-months, memory retrieval appeared to be particularly constrained by intrinsic contextual details, a constraint that was robust across procedural variations that alleviate context-shift effects in other age-groups (Experiment 5). Nonetheless, providing infants with a unique environment for learning and retrieval helped them to retrieve memory across an intrinsic contextual change, indicating that extrinsic context may perform a disambiguating function later in infancy (Experiment 6).

Finally, Experiments 7 to 9 used an EEG study to explore the processes underlying contextual influences on memory retrieval wirh adults. A change of room selectively impaired the purported neural correlates of recollective-based recognition memory, indicating that investigating the development of recollection in infancy may be an important step towards understanding contextual influences on memory in development.

Taken together, these studies show that similar contextual features are encoded in memory from infancy to adulthood. Contextual details exert progressively less influence over memory retrieval over the first year of life, likely through a combination of both the maturation of brain regions involved in memory, and experience of learning and remembering in a variety of settings.

Chapter 1: Introduction

1.1. Studying infant memory

Learning and memory are important skills in the infancy period. For example, the infant needs to learn and remember the rules and categories that govern the physical and social worlds. As the infant develops independent locomotion, he needs to learn and remember how to navigate around his house. In order to avoid approaching the wrong people, the infant needs to learn to recognise his parents, other members of his family, and his friends. Studying memory in infancy characterises a vital mediating link between experience and behaviour in development.

Traditional procedures used to assess memory in adulthood typically employ verbal stimuli or instructions, and are clearly unsuitable for preverbal infants. Measuring memory in infancy requires paradigms that enable infants to 'show' us what they know. Many such paradigms have been developed over the last 50 years (reviewed by Hayne, 2004; Rovee-Collier, Hayne & Colombo, 2001), some of which are discussed in more detail in later sections. In general, these paradigms involve the infant being exposed to a stimulus during the 'encoding' session, and subsequently being placed in a 'test' situation that enables memory retrieval to be measured. Memory measures might include the length of time infants spend looking or playing with a familiar stimulus, what they choose to do with that stimulus, where they search for that stimulus, or their neural response to a familiar stimulus or event. 'Remembering' is operationally defined as 'successful' performance in the test session, typically in comparison with a within- or between-subjects control condition. Infant memory paradigms have provided a wealth of information about the development of memory in the first two years of life.

1.2. Memory at birth

Research with newborn infants indicates the starting point of memory development. Beginning in the 1980s, an innovative research program has revealed that learning begins in the womb. For example, DeCasper and Fifer (1980) found that newborns sucked a non-nutritive nipple more to hear a recording of their mother's voice than to hear an unfamiliar female voice. The authors attributed this finding to recognition of characteristics of the mother's voice learned during the foetal period. In a follow-up study, newborns whose mother had repeatedly read a particularly story aloud during the last 6 weeks of pregnancy sucked more to hear a tape-recording of the familiar story than of a novel story (DeCasper & Spence, 1986). More recently, by measuring foetal heart rate Kisilevsky and colleagues found that foetuses recognise their mother's voice in the third trimester of pregnancy (Kisilevsky *et al.*, 2003).

Newborn infants also learn and remember stimuli experienced shortly after birth. For example, newborn infants recognise their mother's face for up to 15 minutes after it was last seen (e.g., Bushnell, 2001; Bushnell, Sai & Mullin, 1989; Field, Cohen, Garcia & Greenberg, 1984), and breast-fed infants recognise her axillary odour 12 hours after a familiarisation procedure (Porter, Balogh & Makin, 1988). Newborn infants do not only remember biologically significant information about their mother, but they also remember the faces and actions of unfamiliar people (e.g., Meltzoff & Moore, 1983; Meltzoff & Moore, 1989; Nagy & Molnar, 2004; Pascalis & deSchoenen, 1994). For example, 3- to 4-day-old infants who are shown unfamiliar faces remember them after a 2-minute delay (Pascalis & deSchonen, 1994), and newborns can replicate facial movements like tongue protrusion that they have previously seen an experimenter perform (e.g., Meltzoff & Moore, 1983; Meltzoff & Moore, 1989). Finally, newborns also remember non-social stimuli (e.g., Streri & Gentaz, 2003; 2004; Turati, Simeon & Zanon, 2003). For example, newborn infants prefer to visually explore an object that they have previously explored tactilely than to visually explore a novel object, provocative evidence of early cross-modal recognition (Streri & Gentaz, 2003, 2004). Evidently, the ability to remember stimuli and events is present, at least in a rudimentary form, in the perinatal period.

1.3. Infant memory development

Newborn infants clearly remember a range of stimuli for at least a short period of time. How does memory develop over the infancy period? Answering this question is challenging, because of the rapid changes in ability, motivation and favoured activities over the first years of life. These changes mean that memory tasks that are suitable for one age group are not necessarily suitable for another. One strategy is to design tasks to measure a particular type of memory, then identify the age at which infants 'pass' that particular task. This might reveal the order in which particular 'types' of memory develop (e.g., Nelson, 1995). However, a large number of factors may influence the success of memory retrieval on a given paradigm, including the complexity of materials used (e.g., Fagan, 1974), the length of the learning session (e.g., Barr, Dowden & Hayne, 1996), the duration of the retention interval (e.g., Hartshorn *et al.*, 1998a), and the degree to which the task loads on other cognitive abilities (e.g., Diamond, Churchland, Cruess & Kirkham, 1999). Simple changes in the parameters of a task may lead to vast differences in the age at which the task is 'passed' (e.g., Diamond *et al.*, 1999).

An alternative approach to exploring memory development is to compare the performance of infants of different ages on tasks that are suitable for a relatively wide age-range, before validating general conclusions with results from other procedures (e.g., Hayne, 2004). With this approach, task variables such as learning time or retention interval can be manipulated, producing a greater understanding of the parameters controlling memory retrieval within and between age-groups. The majority of studies using this approach have been conducted with one of three paradigms: operant conditioning, in which infants are first trained that a particular behaviour produces a salient outcome, then tested for retention of that behaviour (e.g., Davis & Rovee-Collier, 1983; Hartshorn *et al.*, 1998a,b); deferred imitation, in which infants are shown an action then tested for memory of that action (e.g., Barr *et al.*,1996; Klein & Meltzoff, 1999); or visual recognition memory, in which measures are taken of the changes in visual attention that occur as a stimulus becomes more familiar (e.g., Fagan, 1970; Rose, 1981). Studies using these tasks have revealed several principles of memory in infancy (Hayne, 2004), three of which are briefly discussed in the next section.

1.3.1. Principle 1: Older infants require less encoding time

In general, older infants require a shorter period of learning than younger infants to reach the same level of performance on a memory task (Barr *et al.*,1996; Borovsky & Rovee-Collier, 1988; Davis & Rovee-Collier, 1983; Greco, Rovee-Collier, Hayne, Griesler & Earley, 1986; Hill, Borovsky & Rovee-Collier, 1988; Rose, 1983). For example, 2-month-old infants require 3-6-minutes of training in one operant conditioning procedure to meet a learning criterion (Davis & Rovee-Collier, 1983), whereas 3-month-old infants require 2-3 minutes (Greco *et al.*, 1986), and 6-month-old infants require 1-minute (Hill *et al.*, 1988). Between 6- and 12-months, it appears that the encoding time required for memory to persist over a particular retention interval approximately halves (e.g., Barr *et al.*, 1996; Rose, 1983). For example, whereas 6-month-old infants require 20 seconds of familiarisation to a 3-D geometric form to remember it immediately after learning, 12-month-old infants only require 10 seconds (Rose, 1983).

1.3.2. Principle 2: Older infants remember for longer

Older infants typically remember for longer than young infants, despite the fact they typically receive shorter training sessions (Barr & Hayne, 2000; Hartshorn *et al.*, 1998a). For example, in one deferred imitation task, 6-month-old infants remember for 24-hours after six demonstrations of three target actions (taking approximately 90 seconds), and 12- and 18-month-old infants remember for one and two weeks respectively after three demonstrations of the same target actions (Barr & Hayne, 2000). This principle holds across paradigms, despite differences in the absolute duration over which memory persists: for example, in an operant conditioning task 6-month-old infants remember for 2-weeks after two 6-minute training sessions, whereas 12-month-old infants remember for 8 weeks after two 1-minute training sessions (Hartshorn *et al.*, 1998a).

1.3.3. Principle 3: Older infants remember more information

In general, older infants retain more information from a single episode than younger infants (e.g., Rose, Feldman & Jankowski, 2001; Ross-Sheehy, Oakes & Luck, 2003). For example, Rose *et al.* (2001) familiarised 5-, 7- and 12-month-old infants to one to four 3-D objects (each was presented for 3 to 10 seconds, depending on the infant's age), then tested recognition memory for the objects. Twelve-month-old infants remembered three or four of the objects, but the 5- and 7-month-old infants only remembered one or two. Although the age-related decrease in exposure time to the objects must be taken into account, this study shows that the number of items infants remember from a single episode increases with age.

The studies reviewed above reveal that as infants mature, encoding time decreases, and memory capacity and retention duration increase. However, in all these studies the learning and testing sessions were conducted under the same conditions. In more natural settings, infants may need to learn and remember in different circumstances. For example, an infant may watch their sibling play with a particular toy in a particular way in the kitchen. Later, they may come upon their own version of the toy lying on the living room floor. Being able to remember and reproduce what their sibling had done with the toy requires the infant to be able to encode and retrieve memories in different 'contexts'. Exploring the ability to remember 'out-of-context' reveals the range of situations in which infants can retrieve and use their memories. Indeed, Bruner (1969) argued that the interesting thing about memory is not that we possess it, but whether we can retrieve it and use what is relevant.

1.4. Contextual influences on memory retrieval

In adulthood, anecdotal observations indicate that retrieving memory 'out-of-context' is a non-trivial skill. For example, Smith (1988) notes an occasion upon which Ludwig van Beethoven dreamed of a piece of music whilst riding in a coach, which he could not remember until he rode in the same coach the following day. In a more mundane example, it is a seemingly common experience to go upstairs, promptly forget the item one went upstairs for, only to remember it again on returning to the ground floor. In this case a change of context, from downstairs to upstairs, appears to preclude memory for the sought item. Understanding the ability to remember out-of-context entails understanding the influence of a context change on memory retrieval.

There is a long tradition of experimental research into the influence of a context change on memory retrieval in adulthood (reviewed by Davies, 1988; Smith, 1988, Smith, 1994; Smith & Vela, 2001), and a parallel research field with animals (reviewed by Balsam & Tomie, 1985; Bouton, Nelson & Rosas, 1999). This research provides valuable insights into contextual memory that can be used to guide and interpret studies with infants on this topic.

1.4.1. Definitions of 'context'

In order to study the influence of context on memory retrieval, it is important to define the term 'context'. Broadly, the word 'context' is used to refer to any information that is not the 'to-be-remembered' or 'target' information in a particular task. For example, in a shape recognition task participants might be asked to identify whether a particular shape was seen earlier in the experiment. In this case, the shapes of the test stimuli would be the target information, and any other information (including potentially irrelevant details of the test stimuli, such as their colour) could be termed 'context'. The range of attributes that have been referred to as 'context' cover all modalities, including internal states (caused by drugs or unpleasant experiences; e.g., Overton, 1985), odours (e.g., Aggleton & Waskett, 1999), tastes (e.g., Baker, Bezance, Zellaby & Aggleton, 2004), auditory stimuli (e.g., Honey & Good, 2000), or visual cues (either alone or in conjunction with other cues; e.g., Murnane, Phelps & Malmberg, 1999). Some studies manipulate single features (e.g., Ecker, Zimmer & Groh-Bordin, 2007b), whereas others manipulate large collections of attributes simultaneously (e.g., Godden & Baddeley, 1975, 1980). The details included in the definition of 'context' may thus vary widely between studies.

In response to the wide scope of the term 'context', researchers have empirically and theoretically distinguished between different forms of context (Baddeley, 1982; Godden & Baddeley, 1980; Smith, 1988; Smith & Vela, 2001). For example, Smith (1988) distinguishes internal context (conditions inside the participant such as their mood state), from external context. External context can be further subdivided into intrinsic context (obligatorily-processed stimulus attributes such as the meaning of a word) and extrinsic context (Godden & Baddeley, 1980). Dalton (1993) divides extrinsic context into local context (fast-changing and specific, such as the background upon which a stimulus is presented) and global context (slow-changing and general, such as the room of testing). Whereas these divisions indicate that it is important to consider the relationship between context and the target stimulus (also see Baddeley, 1982), other distinctions indicate the importance of considering the relationship between the contextual element and the ongoing task (e.g., Smith, 1988; Smith & Vela, 2001). For example, Smith and Vela (2001) distinguish between non-incidental and incidental contexts, where incidental contexts are not directly relevant to the ongoing task, and non-incidental contexts are directly relevant. The terminology in this section will be used throughout the present thesis.

1.4.2. Context-shift effects and their interpretation

Contextual influences on memory are often studied by investigating 'context-shift effects'. In such studies, an aspect of the context of learning is changed between the learning and test sessions, and the impact on memory retrieval is noted. For example, in a seminal study, Godden and Baddeley (1975) taught a list of words to a group of divers, which they were subsequently asked to recall. Divers who learned and remembered the words in the same physical environment (either on land or underwater) recalled significantly more words than divers who learned and remembered the words in different physical environments. The negative impact of a context change between learning and retrieval on performance on a memory test can be termed a 'context-shift effect'. Context-shift effects can be caused by a large number of different contextual changes, from the flavour of chewing gum consumed (Baker, Bezance, Zellaby & Aggleton, 2004) to the experimental room in which learning occurs (e.g., Dalton, 1993). The presence of a context-shift effect indicates that information is remembered more poorly out of the context in which it was learned. Importantly, the specific collections of features defined as the learning and testing contexts are typically counterbalanced between or within participants, to ensure that any context-shift effect cannot be attributed to the specific characteristics of one of the contexts used.

The interpretation of context-shift effects is typically guided by the encoding specificity principle (ESP; Tulving & Thompson, 1973), which proposes that memory retrieval is governed by the interaction between the contents of the memory trace, and at the cues present at retrieval. The closer the match, the more likely that memory retrieval will be successful. Thus, if memory retrieval is poorer after a context change (provided alternative explanations have been ruled out), context was encoded in memory with the target items. Demonstrating that a contextual detail has been encoded in memory may be particularly important when working with infants, who cannot be explicitly asked to report the contextual details that they remember.

There are two ways in which a context-shift effect could be produced. First, the context of learning could provide retrieval cues to associated target information. For example, Lehmann, Carfagnini, Yamin & Mumby (2005) found that rats with hippocampal damage had poorer memory for a probe-shock association than control rats when tested in the environment of learning. However, when tested out of the learning environment, performance was equivalent for the two groups. As the data did not suggest a floor effect, it appears that the rats with hippocampal lesions could not benefit from the contextual cues that control rats utilised when learning and testing occurred in the same environment. Secondly, a context-shift effect may result if the absence of learned contextual information inhibits retrieval of associated target information. For example, Moses, Cole, Driscoll, and Ryan (2005) found that rats with hippocampal lesions performed better than normal rats on the first trial after a testing arena was moved from one room to another, despite equivalent performance in the room of learning. The normal rats presumably performed more poorly in the alternate environment because the mismatched contextual information impeded performance, an inhibitory effect that did not appear to influence the performance of the rats with hippocampal lesions. Thus, any context-shift effect could result from inhibition of retrieval in the alternate context, facilitation of retrieval in the context of learning, or both.

The absence of a context-shift effect can also result from two processes. First, contextual information may not have been encoded in memory in the first place, or may have been forgotten by the time of the test session. For example, a context-shift effect may not be seen when memory is tested after a long delay, unless participants are reminded of the context in which learning took place (e.g., Zhou & Riccio, 1994). Presumably, remembering the context of learning at the time of retrieval is an important determinant of context-shift effects. Secondly, contextual information may have been initially encoded in memory, but have little or no detectable impact on the retrieval of target information. When telling stories from the past, we often recall details of the context of an event whilst presently being in a different setting. The ability to retrieve a memory that includes contextual information in a different context is sometimes termed 'generalisation'. Contextual encoding and generalisation are thus important processes to consider when exploring the ability to remember out-of-context.

1.5. The neural basis of contextual memory

In the 1980s, research on the neural structures involved in contextual memory led a number of researchers to propose that neurological immaturity would prevent infants from encoding details that typically comprise the 'context' of an event (e.g., Nadel, Willner & Kurtz, 1985; Nadel & Zola-Morgan, 1984; see also Schacter & Moscovitch, 1984). This idea stemmed from two observations: that the hippocampus (a brain structure situated in the medial temporal lobe; Figure 1) is important in contextual memory (e.g., Hirsh, 1974), and that infant rats (around Post Natal Day (PND)18) have an immature hippocampus (Altman & Bayer, 1975; Rudy & Morledge, 1994). The view that infants fail to encode contextual details in memory is still occasionally expressed: a recent review stated that "[research is] consistent with the notion that *context-free*, incidental mnemonic abilities *precede the development of context-rich memory*, which only gradually emerges during childhood" (Bachevalier & Vharga-Khadem, 2005, p 169; italics added for emphasis). To evaluate the assumptions of this proposal, the next sections consider evidence pertaining to the neural substrates of contextual memory, and their development.

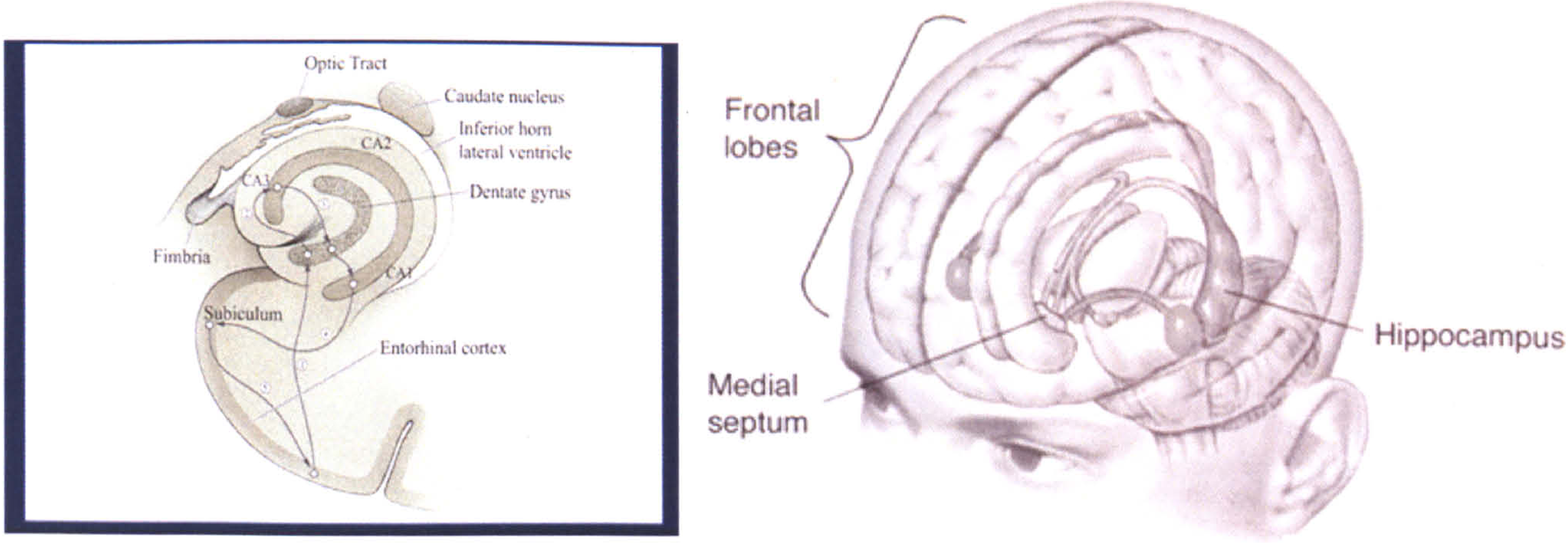

Figure 1.1. The anatomy of the human hippocampus (left) and its position in the brain (right).

Reproduced from Davinsky, 2004. and White, 2004 respectively.

1.5.1. Contextual memory in the mature brain

Regions of the medial temporal lobe, such as the hippocampus, and other connected structures such as the frontal cortex have long been associated with some (though not all) types of memory function (reviewed by Simons & Spiers, 2003; Squire, 2004). The hippocampus, areas of the medial temporal lobe and the frontal cortex are also involved in contextual memory (Cansino, Maquet, Dolan & Rugg, 2002; Davachi, Mitchell & Wagner, 2003; Goh *et al.*, 2004; Ranganath *et al.*, 2003; Summerfield & Mangels, 2005; reviewed by Burgess, Maguire & O'Keefe). For example, in a functional magnetic resonance imaging (fMRI) study, Cansino *et al.* (2002) found that correct memory for an item and its source (location on the screen) were predicted by greater activity in the right hippocampal formation and the left prefrontal cortex during encoding. Frontal and posterior regions may also interact to produce contextual memory during retrieval. In an electroencephalogram (EEG) study, Summerfield and Mangels (2005) found that correct item and colour memory was correlated with greater coherence in the theta band (4-8Hz) activity measured over frontal and posterior scalp areas. This theta band activity is though to reflect functional coupling of the two areas. Coherent theta oscillations may provide one way in which activation in the medial temporal lobe, and activation in the frontal lobes, could interact to produce contextual memory retrieval.

The hippocampus may be *necessary* for some aspects of contextual memory, such as the influence of incidentally-encoded contextual information on memory retrieval, in human adults (Chun & Phelps, 1999; Ryan & Cohen, 2004; Ryan, Althoff, Whitlow & Cohen, 2000) and other vertebrate species (Ennaceur *et al.*, 1997; Mumby, Gaskin, Glenn, Schramek & Lehmann, 2002; though see Eacott & Norman, 2004; Gaffan, 1994). For example, patients with hippocampal damage exhibit impaired performance in a task where surrounding stimuli predict the location of a target stimulus (Chun & Phelps, 1999). Similarly, rats with hippocampal lesions perform differently to control rats on tasks that test memory for the incidentally-encoded association between an object and its context (Mumby *et al.*, 2002). However, hippocampal damage has less effect on contextual memory in other circumstances. For example, extensive exposure to contextual information enables rats with hippocampal lesions to remember a context-shock association (e.g., Young, Bohneck & Fanselow, 1994), and the hippocampus may be unnecessary for processing contextual information when context is the only predictive information in a task (Good & Honey, 1991), or when contextual changes are subtle (McDonald *et al.*, 1997). Thus, the hippocampus may only play a crucial role in contextual memory when the context is relatively novel, and incidental to the experimental task.

In line with the observation that the hippocampus may or may not be necessary for contextual encoding, context-shift effects may or may not be attenuated by hippocampal damage. Some studies find decreased context-shift effects in rats with hippocampal damage (e.g., Good, de Hoz & Morris, 1998; Honey & Good, 1993; Moses *et al.*, 2005; Winocur, 1997). For example, Honey and Good (1993) found that rats with hippocampal lesions do not exhibit reduced latent inhibition (a retardation in learning about a stimulus that has previously been uninformative) after a context change, unlike control rats. Conversely, context-shift effects are sometimes enhanced in rats with hippocampal lesions (Melik, Babar, Ozen & Ozgunen, 2006; O'Brien, Lehmann, Lecluse & Mumby, 2006; Winocur & Olds, 1978). For example, O'Brien *et al.* (2006) found that control rats recognised a familiar object when learning and testing occurred in different contexts over a 15-minute delay, but rats with hippocampal lesions did not, despite normal performance in the learning context. Clearly, even incidentally-presented contextual information can sometimes influence memory retrieval in the absence of the hippocampus (reviewed by Maren, Anagnostaras, & Fanselow, 1998; Rudy *et al.*, 2004). Although the hippocampus does play an important role in contextual memory, its absence does not leave memory 'context-free'.

1.5.2 Contextual memory in the immature brain

Infant rats (PND 17-19), who have an immature hippocampal formation (e.g., Altman & Bayer, 1975; Rudy & Morledge, 1994) but can participate in paradigms typically used with adult rats, provide a good opportunity to explore the relationship between hippocampal development and contextual memory. Evidence that contextual memory is immature in infant rats comes from the observation that young rats sometimes show smaller context-shift effects than older rats (Rudy, 1994; Yap & Richardson, 2005). Apparently, young rats encode contextual information, but this information has less influence on memory retrieval than in older rats. For example, in a latent inhibition paradigm Yap and Richardson (2005) found no context-shift effect when both learning and retrieval occurred at PND 18 to 20. In contrast, a context-shift effect was found when retrieval occurred at PND 25, irrespective of whether learning occurred at PND 18 or 25. Thus, rats encoded context when they were 18-days old, but contextual information only influenced memory retrieval in 25-day-old rats.

Although Young and Richardson found no evidence that memory retrieval in 18-day-old rats is influenced by a context change, this age-group do sometimes show significant context-shift effects (Richardson, Riccio & McKenney, 1988). Indeed, contextual information sometimes plays a larger role in infant learning and memory than for adults. For example, the same distinctive pharmacological state, or ambient odour, present at both conditioning and testing facilitates learning in infant but not adult rats (Concannon, Smith, Spear & Scobie, 1978; Richardson, Riccio & Axiotis, 1986; Richardson, Riccio & Jonke, 1983). Clearly, context influences memory retrieval in infant rats under some circumstances, although contextual memory is not adult-like in nature (e.g., Brasser & Spear, 2004). Thus, hippocampal immaturity does not appear to lead to 'context-free' memory, at least in infant rats.

1.6. Theoretical perspectives on the neural basis of contextual memory

One way to clarify the role of the hippocampus in contextual memory is to take a theoretical perspective. Two theories that are particularly relevant to understanding the role of the neural systems involved in contextual memory, relational memory theory (e.g., Eichenbaum, Otto & Cohen, 1994; Eichenbaum & Cohen, 2001), and conjunctive representations theory (e.g., O'Reilly & Rudy, 2001), are introduced in the next sections.

1.6.1. Relational Memory Theory

Memory may not be a unitary ability (reviewed by Eichenbaum & Cohen, 2001). One division that has been widely accepted is the declarative/nondeclarative distinction (reviewed by Squire, 2004), which was initially motivated by the observation that patients with amnesia are typically poor at remembering facts and events, but not impaired in skill learning (e.g., Cohen & Squire, 1980; Scoville & Milner, 1975).

Declarative memory (the memory that is typically impaired in amnesia) comprises semantic memory (memory for facts) and episodic memory (memory for events; e.g., Tulving, 1972, 1983, 2002), and is typically measured by explicit retrieval tasks such as recall (in which participants retrieve a piece of information from memory) and recognition (in which participants identify that an item of presented information has been previously encountered). Declarative memory has been linked to the functioning of the hippocampus and surrounding structures (reviewed by Squire, 2004). Nondeclarative memory (typically spared in amnesia) includes the acquisition of skills, and other nonconscious forms of learning such as priming (the effect of prior processing on subsequent processing speed). Nondeclarative memory is thought to be accomplished by a variety of neural systems outside the medial temporal lobe (reviewed by Gabrieli, 1998).

In recent years, declarative memory has been reconceptualised by some authors as 'relational memory' (e.g., Chun & Phelps, 1999; Eichenbaum *et al.*,1994; Ryan & Cohen, 2004). Relational memory is memory for the "relevant contingencies between ... items and the structure of any already established memory organisation that involves those items" (Eichenbaum *et al.*, 1994, p 467). In RMT, the medial-temporal lobe does not act as a unitary memory system. Rather, its subcomponents have specific roles, an attractive feature of RMT as there is increasing evidence for the existence of functional divisions within the medial-temporal lobe (reviewed by Murray & Wise, 2004). Eichenbaum, Yonelinas and Ranganath (2007) present a range of data in support of the proposal that the perirhinal cortex stores representations of individual items (after an initial period of a few minutes where they are processed in the hippocampus), the parahippocampal cortex stores contextual information, whereas memory for item-context relations remains stored in the hippocampus[1]. Under Relational Memory Theory (RMT), the 'relational' memories stored by the hippocampus are held to be 'flexible'; that is, they can be accessed by novel routes or pathways, "permitting the expression of memories in various, even novel, situations" (Eichenbaum *et al.*,1994, p 467) . This "representational flexibility" (Eichenbaum, 1997), is held to be a key property of relational memory. Thus, learning and remembering in different contexts can be attributed to representational

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[1] This has also been termed the 'Binding-in-Context model' (Eichenbaum *et al.*, 2007; Diana *et al.*, 2007).

flexibility, providing that the contextual information in question was encoded and associated with memory for the target items.

In contrast, memory stored outside the hippocampal formation is proposed to be 'inflexible', such that retrieval is closely tied to the conditions of encoding. Extra-hippocampal memories "involve the tuning or biasing of items within separate processing modules of the brain operating in isolation ... Individual representations can incorporate combinations of stimulus elements, but such processing involves the *fusion* of stimulus elements into a single representation lacking the property of compositionality" (Eichenbaum *et al.*,1994, p 467, italics added for emphasis). 'Compositionality' refers to a property that enables the "simultaneous representation both of the separate constituent pieces of knowledge and the larger structure they serve" (Cohen, Poldrack & Eichenbaum, 1997, p 141). Representations that are not compositional "can only be expressed or otherwise exert their influence under testing conditions that.... constitute a repetition of the original learning situation" (Cohen *et al.*, 1997, p. 142). In other words, when single elements have been fused (or 'unitized'; e.g., Yonelinas, Kroll, Dobbins & Soltani, 1999) into a noncompositional representation they cannot be accessed independently of each other.

How does RMT account for the effects of a hippocampal lesion on contextual memory? Under RMT, hippocampally-dependent memory includes item-context links, but representational flexibility enables retrieval to be minimally affected by a context shift. Nonetheless, a small context-shift effect may occur because there are fewer retrieval cues to the target item when learned contextual information is absent during the test session. In the absence of the hippocampus, item-context associations will be less likely to form. This could explain why rats with hippocampal lesions sometimes show reduced context-shift effects (e.g., Good, de Hoz & Morris, 1997; Honey & Good, 1993; Moses *et al.*, 2005; Winocur, 1997). However, extra-hippocampal representations might include salient contextual information if it can be blended with target information, particularly when context is directly relevant to the task solution. This could explain why rats with hippocampal lesions are often able to learn tasks that require intentional contextual processing (e.g., Good & Honey, 1991; McDonald *et al.*, 1997). When contextual information is blended into the memory trace, the absence of this information during the test session is likely to have a profound effect on retrieval. The inclusion of contextual information into a blended representation could explain why some studies find greater context-shift effects in rats with hippocampal lesions (e.g., O'Brien *et al.*, 2006). Thus, RMT provides a relatively comprehensive account of the relationship between contextual memory and the hippocampus (reviewed by Moses & Ryan, 2006).

1.6.2. Conjunctive Representations Theory

An alternative account of the relationship between contextual memory and the hippocampus is provided by Conjunctive Representations Theory (CRT; reviewed by O'Reilly & Rudy, 2001; Rudy, Huff & Matus-Amat, 2004), which has its roots in associationism. CRT proposes that there are two types of representations that can enter into associations. *Elemental representations* stand for individual stimuli, such as a light, which can be associated with a reward, such as food. However, these representations are not always sufficient to solve a task. For example, in a negative patterning task a tone might predict reward, a light alone might predict reward, but a tone and a light together might predict no reward (e.g., Rudy & Sutherland, 1989). In this case, a *conjunctive* representation of 'light + tone' is formed, which acquires an inhibitory association to the reward representation. This inhibitory association counters the excitatory associations between the reward and the elemental representations of the light and tone, allowing the task to be solved. Importantly, conjunctive associations are not simply the sum of their component stimuli; rather, they are closer to a new stimulus that is used to represent the presence of both constituent stimuli (O'Reilly & Rudy, 2001). As such, it has been argued that conjunctive representations are similar to the 'fused' representations of RMT (Moses & Ryan, 2006).

Although in CRT conjunctive representations can be formed in the cortex over long periods of explicit training (O'Reilly & Rudy, 2001), the hippocampus "rapidly and automatically [stores] conjunctive representations just as a function of the organism attending to its environment" (Rudy *et al.*, 2004 p. 2). When incoming information matches part of a stored conjunctive representation, the hippocampus is specialised for two competing processes: pattern completion, where the incoming information acts as a retrieval cue for the stored conjunctive representation, and pattern separation, where the incoming information is distinguished from stored conjunctive representations (e.g., Atallah, Frank & O'Reilly, 2004; Norman & O'Reilly, 2003; O'Reilly & Rudy, 2001). Pattern completion is more likely to occur if the incoming and stored patterns overlap to a greater degree. Pattern completion is thought to be crucial to declarative memory, because it enables memory retrieval to proceed from a small number of retrieval cues (Rudy *et al.*, 2004; Squire, 1992). Within the hippocampus, area CA1 is thought to be important in driving pattern completion through its graded response to stimuli, and the dentate gyrus and area CA3 are thought to be important in driving pattern separation through the sparseness of the representations they provide (O'Reilly & McClelland, 1994; Vazdarjanova & Guzowski, 2004).

Under CRT, contextual information can be included in conjunctive representations, and can thus influence the competition between pattern completion and pattern separation in the hippocampus (O'Reilly & Rudy, 2001). During a memory test, the degree of similarity between the learning and testing contexts may influence the neural competition between pattern completion and pattern separation, and hence the likelihood of successful memory retrieval. Thus, CRT can readily account for context-shift effects that occur through hippocampal processing. However, contextual effects on memory retrieval can also occur through extra-hippocampal processing in two main ways. First, the context may involve a salient feature that is elementally represented and can be directly associated with reward. The loss of this feature after a context-shift would reduce the magnitude of the learned response. Under CRT, this mechanism may not be very important under normal circumstances, because a mature hippocampus inhibits associations between rewards and elemental representations of contextual features (Rudy *et al.*, 2004). Secondly, contextual information can influence memory retrieval in the absence of the hippocampus if training takes place over many trials, and contextual information is included in extra-hippocampal conjunctive representations that form slowly in the cortex (e.g. Whishaw & Tomie, 1991). Thus, CRT provides a number of ways in which contextual information can negatively influence memory retrieval.

CRT can also explain why a change of context does not typically *preclude* memory retrieval, through three mechanisms that allow memories to be generalised from one setting to another. First, pattern completion in the hippocampus can drive retrieval of memory traces that share common elements with cortical inputs (e.g., Atallah *et al.*, 2004; O'Reilly & Rudy, 2001). However, this is likely to support only limited generalisation, because the hippocampus is biased towards pattern separation (Atallah *et al.*, 2004). Secondly, multiple experiences of similar input patterns lead to 'decontextualisation' – the strengthening of links between common features of an episode, and the weakening of links to more specific features (O'Reilly, 2001). This may co-occur with a transition in the importance of relevant brain areas from the hippocampus to the neocortex (e.g., McClelland, McNaughton & O'Reilly, 1995). Decontextualisation may support generalisation based on categories constructed from perceptual or functional features, but this process is only likely to emerge after many trials. Finally, generalisation can proceed through 'abstraction', the identification of abstract patterns in the prefrontal cortex (Rougier, Noelle, Braver, Cohen & O'Reilly, 2005). For example, abstraction supports the inference that 'open weekdays until 8' means that the store will still be open at 7 on a Tuesday. In humans, the prefrontal cortex continues to develop until puberty, suggesting that this form of generalisation may have a protracted development (Munakata & O'Reilly, 2003).

Both CRT and RMT propose an important role for the hippocampus in contextual influences on memory retrieval. Both theories propose that the hippocampus can also support memory retrieval in alternate contexts (through representational flexibility or pattern completion), although under CRT this function is mainly driven by the frontal cortex (e.g., Munakata & O'Reilly, 2003). Although context can influence memory through extra-hippocampal processes in both theories, this is different to how context influences memory in the presence of a mature hippocampus. Thus, understanding hippocampal development is important for understanding contextual memory in infancy.

1.7. Development of the neural systems involved in contextual memory

In most brain areas, rapid synaptogenesis in the infancy period creates a peak of synaptic density, before the excess synapses are gradually pruned to adult levels (reviewed by Huttenlocher, 1994; Huttenlocher & Dabolkhar, 1997; Nelson, 1999; Webb, Monk & Nelson, 2001). This process follows different timescales in different areas. For example, in the primary auditory and visual cortices synaptogenesis peaks around 3-4 postnatal months, with maximum density reached around 4 months, and pruning is complete by early childhood (2-6 years). However, in the frontal cortex, synapse formation does not reach maximum density until around 15-months, and in the medial frontal gyrus (an area of the frontal cortex) maximum density is not reached until the age of 3.5 years, with pruning continuing into adolescence. Given the role of the frontal cortex in contextual memory and generalisation (e.g., Cansino *et al.*, 2002; O'Reilly, 2001; Rougier *et al.*, 2005), the relatively slow development of this region indicates that some aspects of contextual memory are likely to be immature in infancy (and indeed into childhood; Ofen *et al.*, 2007).

In contrast to the frontal cortex, most features of the hippocampus appear relatively mature in early infancy. For example, in the CA fields of the hippocampus, and in the subiculum, most cells are formed and in their adult locations by birth (Seress, 2001). On MRI scans, the basic gross morphology of the hippocampus is similar to that of adult from at least the age of 3-weeks (Utsunomiya, Takano, Okazako & Mitsudome, 1999). Synaptic proliferation is rapid after birth, and synapses reach their adult levels by around 6-months of age. Thus, most of the hippocampus is mature by the 2-6th postnatal month (reviewed by Bauer, 2004), leading some authors to argue that hippocampal structures could support rudimentary memory formation and retrieval from birth (reviewed by Bachevalier & Vargha-Khadem, 2005; Nelson, 1995). This can be contrasted with the late maturation of the hippocampus in infant rats, from which the prediction that memory would be context-free in infancy was originally derived (e.g., Nadel *et al.*, 1985; Nadel & Zola-Morgan, 1984; see also Schacter & Moscovitch, 1984). Thus, it is plausible that human infants process contextual information in a similar way to adults from very early in development.

Despite the early maturity of some features of the hippocampus, there are nonetheless post-natal developments in the hippocampal region. For example, myelination (a process of neuronal sheathing that increases the speed of signal transmission) in the hippocampal region may last into puberty (Arnold & Torjanowski, 1996; Benes, Turtle, Khan & Farol, 1994). Myelination of the fornix and anterior commissure (two important conduits for inputs and outputs to the hippocampal region) increases over the first two years of life (Utsunomiya *et al.*, 1999). In addition to changes in myelination, there are changes in the size of the hippocampus through development. For example, in cross-sectional MRI and autopsy studies, the hippocampus shows a rapid increase in volume from birth up to the second postnatal year, with slower increases continuing into adolescence (Kretschmann, Kammradt, Kratuhausen, Sauer & Wingert, 1986; Pfluger *et al.*, 1999; Utsunomiya *et al.*, 1999)[2]. Changes in the size of areas of the hippocampus have also been found on MRI scans taken longitudinally between the ages of 4 and 25 years (Gogtay *et al.*, 2004). In this study, the observed changes were not uniform across different hippocampal regions – whilst the anterior subregion decreased in size, the posterior subregion increased in size. Notably, for children and young adults, there is a negative correlation between hippocampal volume and memory performance (van Petten, 2004), indicating that the cognitive implications of a size change are not easy to interpret. Nonetheless, developments in the hippocampal region through the infancy period are likely to impact on memory development.

One area of the hippocampus, the dentate gyrus, undergoes a particularly protracted period of development (e.g., Seress, 2001; Seress, Abraham, Tornoczky & Kosztolanyi, 2001). Indeed, neurogenesis continues in the dentate gyrus into adulthood (Eriksson *et al.*, 1998). Most cells are formed by birth, but the morphology of individual neurons in the dentate gyrus does not appear adult-like until 12-15-months (Seress, 2001). Synaptogenesis increases from 8- to 12-months, and peaks at 16- to 20-months (Seress, 2001). Although the timescale of synaptic pruning in human infancy is presently unclear, pruning in the dentate gyrus of rhesus monkeys (who have similar, though not identical, development in the hippocampal region) is not complete until around 4-5 years

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[2] Notably, the volume of the whole brain also increases rapidly over the first two years of life (e.g., Pfluger *et al.*, 1999; Courschene, Chisum, Townsend *et al.*, 2000).

(Eckenhoff & Rakic, 1991). Further, in human infants myelination does not begin until around 11-months of age in the dentate gyrus (Seress *et al.*, 2001). As the dentate gyrus is thought to be particularly important for driving pattern separation in the hippocampus (O'Reilly & McClelland, 1994; Vazdarjanova & Guzowski, 2004), the immaturity of the dentate gyrus in infancy may reduce the likelihood of similar episodes being represented separately in memory. Under this account, young infants would be more likely to exhibit pattern completion across small contextual changes. However, other authors have proposed that immaturity of the dentate gyrus would lead to limited 'representational flexibility', increasing the likelihood that a contextual change would negatively influence memory retrieval (e.g., Richmond & Nelson, 2007). Exploring the development of contextual memory in infancy may thus provide contributing evidence to the debate between the two major models of contextual memory and the hippocampus (see Moses & Ryan, 2006 for direct comparison).

1.8. Context-shift effects in human infants

Taken together, the research described in sections 1.5, 1.6 and 1.7 undermines the logic of the proposal that memory in infancy is 'context-free' because of hippocampal immaturity (e.g., Nadel & Zola-Morgan, 1984). Although the hippocampus plays an important role in contextual memory, theoretical and empirical studies indicate that the hippocampus is not always *necessary* for contextual information to be encoded or to influence retrieval. Memory in infant rats, who have an immature hippocampus, is influenced by contextual manipulations. Furthermore, in humans, unlike in rats, most features of the hippocampus are mature in early infancy. Thus, evidence from studies of the neural basis of contextual memory provides no support for the idea that memory in human infancy is likely to be context-free. However, there are postnatal changes in the hippocampal region (such as the protracted development of the dentate gyrus) that indicate that contextual memory may undergo postnatal development in human infancy. Furthermore, the frontal cortex, also important in contextual memory, remains immature until adolescence. Research on the neural basis of contextual memory thus indicates that it is important to explore the development of contextual influences on memory retrieval in human infancy. In this section, current knowledge of contextual influences on infant memory retrieval is reviewed.

1.8.1. Insights from the Mobile Conjugate Reinforcement Paradigm (MCRP)

Work on the role of context in memory retrieval in 2- to 6-month-old infants began with an operant conditioning procedure called the Mobile Conjugate Reinforcement Paradigm, or mobile task (reviewed by Rovee-Collier, 2001; Rovee-Collier *et al.*, 2001). In this task, an infant learns that kicking his leg produces contingent movement in a mobile suspended above his crib or playpen. Memory is assessed by measuring kick rate in the absence of reinforcement, during a test session. In order to examine the influence of context on memory retrieval, the cues provided for infants during the test session are manipulated. For example, infants may be tested in the presence of a novel mobile (e.g., Rovee-Collier & Sullivan, 1980), in a different room in their home (e.g., Hayne, Rovee-Collier & Borza, 1991), or with a different distinctive lining to their crib (e.g., Borovsky & Rovee-Collier, 1990). Using the terminology discussed in Section 1.4.1, in the remainder of the thesis details of the mobile will be defined as intrinsic context, the crib liner will be referred to as local extrinsic context (because it is a specific feature of the test setting), and the room of testing will be referred to as global extrinsic context[3].

In the mobile task, memory retrieval in 3- and 6-month-old infants is strongly constrained by intrinsic contextual congruency between encoding and retrieval. When the mobiles used in the learning and testing sessions are identical, 3- and 6-month-old infants remember the mobile task for 2- and 3-weeks respectively (e.g., Butler & Rovee-Collier, 1989; Hill *et al.*, 1988). However, when 3- and 6-month-old infants are presented with a completely novel mobile in the training environment after a 24-hour delay, they show no evidence of memory retrieval (Borovsky & Rovee-Collier, 1990; Fagen, Rovee-Collier & Kaplan, 1976; Rovee & Fagan, 1976), even if training and

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[3] 'Local' context typically refers to specific features that are 'fast-changing'. 'Fast-changing' generally means that contextual features are presented with each stimulus, rather than context that is present throughout the learning session. For example, each one of a series of faces might be presented with a different name. These names would be referred to as local context (Dalton, 1993). In the mobile task, only one stimulus is typically presented. Thus, the slow/fast-changing aspect of the local/global distinction is less relevant than the distinction between specific and general features of the test setting, and it is the latter distinction that is used here.

testing occur in the presence of a distinctive crib liner (Butler & Rovee-Collier, 1989; Hill *et al.*, 1988). Memory may also be precluded by relatively minor changes to the testing mobile. For example, for 3-month-old infants memory retrieval typically fails if more than one component of a five-component mobile is novel (Hayne, Greco, Earley, Griesler & Rovee-Collier, 1986).

Over time, memory for the training contingency typically becomes less constrained by details of the mobile. When learning occurs in the absence of a distinctive crib liner, and memory is tested 3- or 5-days after learning, 3-month-old infants respond equivalently to a novel mobile and the original mobile (Rovee-Collier & Sullivan, 1980). However, when a distinctive crib liner is present during the learning and testing sessions, 3- and 6-month-old infants do not respond to a novel mobile over any delay over which they remember the training mobile (Butler & Rovee-Collier, 1989; Hill *et al.*, 1988). Rovee-Collier and colleagues argue that infants respond to a novel mobile when they have forgotten the specific details of the training stimulus, and can only retrieve memory for the general features of the training situation (reviewed by Rovee-Collier, 2001). When infants remember the specific details of the training stimulus, they realise that the novel mobile is different and do not respond[4]. Providing a distinctive crib liner for learning and retrieval may enable infants to remember the specific details of the training mobile for longer, thus facilitating discrimination over longer retention intervals (Butler & Rovee-Collier, 1989).

Changes in extrinsic contextual information also influence memory retrieval for 3- and 6-month-old infants, but effects depend on the age of the infant and the interval over which retention is assessed (Borovsky & Rovee-Collier, 1990; Butler & Rovee-Collier, 1989; Fagen *et al.*, 1997; Hayne *et al.*, 1991). For example, memory retrieval in 3-month-old infants is unaffected by a change from one distinctive crib liner to another (such as yellow with green squares to blue with red stripes) 1-day after learning, but memory is precluded by the change 3-, 5- or 7- days after learning (Butler & Rovee-Collier, 1989; Rovee-Collier, Griesler & Earley, 1985). Intriguingly, 6-month-old infants show a U-shaped memory function when they are tested over increasing retention

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[4] This is an example of the inhibitory effect a change of context may have on memory retrieval (Section 1.4.2).

intervals in the presence of an altered crib liner. A change of crib liner, or simply the absence of the training crib liner, precludes retrieval over a 1- or 3-day delay, but does not influence retrieval over a 5-, 7- or 14-day delay (Borovsky & Rovee-Collier, 1990). However, over a 3-week delay 6-month-old infants can only be reminded of the training contingency when the same distinctive crib liner is used for training and reminder sessions (Borovksy & Rovee-Collier, 1990), indicating that contextual congruency regains importance at the end of the retention interval.

Other modalities of extrinsic context influence memory retrieval for 3-month-old infants in a time-dependent manner. For example, memory retrieval in 3-month-old infants is unaffected when different music is played during training and test sessions over a 1-day delay, but is precluded over a 7-day delay (Fagen, Prigot, Carroll, Pioli, Stein & Franco, 1997). When 3-month-old infants learn the mobile task in one room in their home, and are tested in a different room, memory retrieval is unaffected over a 24-hour delay, but 2-weeks after learning infants can only be reminded of the mobile task in the same room that they learned the contingency (Hayne*et al.*, 1991). Clearly, the absence of a context-shift effect in infancy does not always indicate that context has been irretrievably forgotten.

Research with the mobile task has shown that 3- and 6-month-old infants encode a wide range of contextual details in their memory representations, and that contextual information places a highly constraining influence on memory retrieval early in infancy. This *contextual specificity* is likely to severely limit the situations in which young infants have access to their memory representations. However, young infants can sometimes retrieve memory out-of-context, even when contextual information has been encoded and remembered (e.g., Borovksy & Rovee-Collier, 1990). This indicates that the development of the ability to retrieve memory out-of-context (generalisation) is important to investigate. However, the mobile task is only suitable for infants of 6-months and younger. Given the age-related changes in memory retrieval that occur over the first two years of life (Section 1.3), and the developmental changes in the neural systems underlying contextual memory reviewed in Section 1.7, it is important to explore the influence of context on memory retrieval in infants of 6-months and older.

1.8.2. Age-related changes in contextual influences on memory retrieval

In the 1980s and 90s, whilst research with the mobile task was demonstrating that memory retrieval in 3- and 6-month-old infants was strongly influenced by contextual congruency, Meltzoff and his colleagues were finding the opposite result using deferred imitation tasks with 12-14-month-old infants (e.g., Barnat, Klein & Meltzoff, 1996; Hanna & Meltzoff, 1993; Klein & Meltzoff, 1999). In a deferred imitation task, memory is tested by observing whether infants reproduce an action that they have previously watched an experimenter produce. In these studies, memory retrieval was remarkably uninfluenced by changes in extrinsic or intrinsic context. For example, Hanna and Meltzoff (1993) found that 14-month-old infants were able to imitate a series of actions they had observed at home when they were tested in the lab 2 days later, and Barnat *et al.* (1996) found that 14-month-old infants showed evidence of deferred imitation when tested with objects of a different size in a different room in the University over a ten-minute delay. Comparing these findings to those from the mobile task, memory retrieval in older infants is either less influenced by a contextual change than memory retrieval in younger infants, or contextual information plays different roles in the deferred imitation and mobile tasks. Evaluating these possibilities requires studies that span the 6- to 12-month-age range.

One approach, taken by Hartshorn *et al.* (1998b), was to compare the performance of 3- and 6-month-old infants in the mobile task with the performance of 9- and 12-month-old infants in a related operant conditioning task, the 'train task' (Hartshorn *et al.*, 1997). The procedures are similar, but in the train task the infant must push a button to move a train, rather than kick his leg to move a mobile. In this task, 9- and 12-month-old infants were only affected by a change of intrinsic context over relatively long delays (e.g. 28 days), whereas 3- and 6-month-old infants were affected by intrinsic context changes over much shorter delays (24 hours). Thus, intrinsic contextual changes affected memory over shorter absolute delays in younger infants than in older infants. A similar pattern was found for 3-, 9- and 12-month-old infants tested with an extrinsic context change (although not for 6-month-old infants; see Section 1.8). These results suggest that contextual information becomes less important with age, such that older infants only require contextual congruency when memory is tested over a long retention interval.

One limitation of Hartshorn *et al.* (1998b) is that intrinsic and extrinsic context were defined in different ways for infants of different ages. In the mobile task (for 3- and 6-month-olds) extrinsic context was defined as the colour and pattern of a distinctive crib liner, and intrinsic context was defined as the colour and form of the mobile. In contrast, in the train task (for 9- and 12-month-olds) extrinsic context was defined as the room in which testing occurred, whereas intrinsic context included the colour (but not the form) of the train, and the immediate surroundings of the train set. These included the colour and pattern of a distinctive backdrop that was identical to those used as extrinsic context in the mobile task. Thus, it is difficult to determine whether the age-related changes observed by Hartshorn *et al.* (1998b) were driven by systematic changes in methodology, or changes in the way infants of different ages use contextual information in memory retrieval.

A second approach to studying developmental change in contextual memory focussed on using the same paradigm and contextual manipulation with infants of different ages. For example, in the puppet deferred imitation task, the infant observes a number of target actions modelled on a hand-held glove puppet, and is subsequently given the opportunity to reproduce those actions (e.g., Barr *et al.*, 1996; Hayne *et al.*, 2000). Research with this task has provided more robust evidence of age-related changes in the influence of contextual congruency on memory retrieval (e.g., Hayne *et al.*, 2000; Learmonth, Lamberth & Rovee-Collier, 2004; 2005). For example, Hayne *et al.* (2000) explored whether 6-, 12- and 18-month-old infants could learn and remember the puppet task in different locations over a 24-hour delay. Infants were shown the target actions either at home, or in the laboratory. Subsequently, memory retrieval was tested in the learning location, or in the alternate location. Twelve- and 18-month-old infants showed equivalent levels of memory retrieval in both conditions, whereas 6-month-old infants only showed evidence of memory when the demonstration and test sessions occurred in the same location. In contrast, when infants were tested in the same location, but with a puppet that differed in form and colour from the demonstration puppet, only 18-month-old infants showed evidence of memory retrieval after a 24-hour delay. Thus, age-related changes in the influence of a context change on memory may differ for intrinsic and extrinsic contextual features.

Another task that has been used to study age-related changes in contextual influences on memory retrieval is a measure of visual recognition memory, the Visual Paired Comparison (VPC) task (Haaf, Lundy & Coldren, 1996; Robinson & Pascalis, 2004). For example, Haaf *et al.,* (1996) showed 6-month-old infants a familiarisation stimulus on a brightly coloured and patterned background. Recognition memory was tested immediately by presenting the familiar stimulus and a novel stimulus on either the same background as during familiarisation, or on a novel background. Six-month-old infants only exhibited recognition memory when the background was the same during learning and retrieval. Subsequently, Robinson and Pascalis (2004) tested 6- to 24-month-old infants in a similar task. Whereas 6- and 12-month-old infants showed no evidence of recognition memory for the familiar stimulus when it was presented on an alternate background, 18- and 24-month-old infants recognised the familiar stimulus in both conditions. Visual recognition memory is particularly constrained by details of the background upon which a stimulus is presented for 6- and 12-month-old infants in this task.

Broadly, between 6- and 18-months there may be age-related changes in the success with which infants can retrieve memory across changes in the intrinsic and extrinsic context of encoding and retrieval. This is particularly interesting in light of the evidence reviewed in Section 1.7 concerning the development of the brain structures involved in contextual memory over the infancy period. Indeed, some authors have interpreted changes in contextual influences on memory retrieval as reflecting age-related change in 'representational flexibility' (e.g., Hayne, 2004; Hayne *et al.*, 2000; Robinson & Pascalis, 2004). However, there are disparities in the timescale over which change occurs in different paradigms. In the VPC, infants show no evidence of memory retrieval when the background of a stimulus is changed before the age of 18-months (Robinson & Pascalis, 2004). In contrast, in the deferred imitation task, by 12-months memory retrieval is unaffected by a change from home to the lab between the learning and test sessions (Hayne *et al.*, 2000). Both authors attribute memory retrieval in the changed context condition to 'representational flexibility'. If this is the case, the development of representational flexibility is gradual and non-uniform.

1.9. Variables that influence the magnitude of context-shift effects

Given that the developmental trajectory of contextual influences on memory retrieval is non-uniform, it is important to explore contextual memory under different conditions. This may illuminate the processes underlying developmental changes in contextual memory, and reveal the range of circumstances in which infants of different ages can access their memory representations. To do this, it is necessary to identify the variables that might have an important effect on the manner in which context influences memory retrieval. In the next section, research with human adults, infants and animals is used to identify five important influences on contextual memory, and the implications these factors have for exploring developmental changes in contextual memory.

1.9.1. Retention interval

Research with animals, human adults and infants reveals that the relationship between retention interval and the magnitude of a context-shift effect is complex. Some studies find an increase in the magnitude of context-shift effects over time (for meta-analysis see Smith & Vela, 2001), some find a decrease (e.g., Hartshorn *et al.*, 1998b; Rosas & Bouton, 1997; Zhou & Riccio, 1996), and others find non-monotonic changes (e.g., Bertsch & Sanders, 2005; Borovsky & Rovee-Collier, 1990; Land & Riccio, 1998). For example, Land and Riccio (1998) found that rats trained in a passive-avoidance task show a context-shift effect (where the contexts were rooms that differed in lighting, odour, size and noise) after delays of 1- and 21-days, but not after 7- or 14-days. In a similar paradigm, rats given a saline injection after training in a passive-avoidance task showed a context-shift effect after 1- or 14-days, but not after 7-days (Land & Riccio, 1999). Conversely, Bertsch and Sanders (2005) found that verbal memory in adult humans was more influenced by a background change when memory was tested after 2-days than when it was tested after 1- or 7-days. Clearly, it is important to consider the interval over which retention is assessed when exploring contextual memory in infancy.

Deciding on an appropriate retention interval is particularly important when examining age-related changes in contextual influences on memory retrieval. As reviewed in Section 1.3, there are large developmental changes in the duration of memory in particular tasks, indicating that there are age-related changes in rates of forgetting.

Thus, the same absolute delay may fall at different points in the forgetting function of infants of different ages. Testing infants of different ages over the same absolute delay may lead to differences in contextual influences on memory retrieval that are an artefact of testing at different points in the forgetting function. This difficulty also applies to comparing results across paradigms that have different forgetting functions. One way to alleviate this problem is to test memory over short delays. Most retention-interval related changes in the magnitude of context-shift effects appear to occur on a scale of days, rather than minutes (e.g., Bertsch & Sanders, 2005; Borovksy & Rovee-Collier, 1990; Land & Riccio, 1998). Thus, age-related differences in rate of forgetting should not impact too heavily on the magnitude of a context-shift effect when memory is tested over a few minutes' delay.

A further disadvantage of exploring memory over long retention intervals when studying developmental change is the different ages at which infants learn and are tested in such procedures. Research with both infant rats (Yap & Richardson, 2005) and infant humans (Hartshorn & Rovee-Collier, 2003) has revealed that infants may respond according to their age at testing, rather than their age at learning. For this reason, when infants are tested over very long retention intervals, it is difficult to establish whether the magnitude of the context-shift effects obtained reflects the age the infant learned the information, or the age at which it was retrieved. Measuring context-shift effects over short delays may thus provide a more appropriate comparison for the examination of age-related changes in memory.

1.9.2. Type of task

Some paradigms are more sensitive to a context-shift than others (reviewed by Bouton, 1993; Smith & Vela, 2001). An important observation is that recall memory is typically more context-sensitive than recognition memory. Indeed, some studies have found no effect of a context-shift on a recognition memory measure (e.g. Fernandez & Alonso, 2001; Fernandez & Glenberg, 1985; Godden & Baddeley, 1975, 1980; Smith, Glenberg & Bjork, 1978). However, several studies have demonstrated an effect of a context-shift on recognition memory (e.g., Dalton, 1993; Richmond, Sowerby, Colombo, & Hayne, 2004; Russo, Ward, Geurts & Scheres, 1999). In a recent meta-analysis, Smith and Vela (2001) found no significant difference between the effect sizes of studies using free recall, cued recall and recognition measures. This indicates that when many studies are combined, context changes have a reliable effect on recognition memory that may not differ from the effect of a context change on recall memory. Although this resolves some debate, it cannot account for the fact that the same contextual manipulation may influence performance on a recall but not a recognition memory measure (e.g., Godden & Baddeley, 1975; 1980; Smith *et al.*, 1978).

The observation that some studies find context-shift effects on recognition memory measures, and others do not, has led to several theoretical models of the conditions under which recognition memory is sensitive to a context-shift effect. The major theories can be roughly split into unitary and dual-process models. Unitary-process models assume that at recognition, all the attributes in memory that match features in the environment are activated, and recognition decisions are based on the global sum of this activation (reviewed by Clark & Gronlund, 1996). There are three versions of unitary-process model that account for the mixed evidence of context-shift effects in recognition memory. First, the 'overshadowing/outshining hypothesis' (Smith, 1988) proposes that, given sufficient effort, the context can be suppressed during either the learning (overshadowing) or test (outshining) sessions. This prevents the formation of item-context links that are proposed to underlie context-shift effects. Second, the 'cue-overload' hypothesis states that a context that is associated with more target items will provide a weaker cue to each item individually (and hence produce smaller context-shift effects) than will a context that is uniquely associated with a cue (Earhard, 1967; Rutherford, 2004; Watkins, 1979; Watkins & Watkins, 1975). Finally, the Item, associated Context and Ensemble model (ICE; Murnane & Phelps, 1993, 1994, 1995; Murnane *et al.*, 1999) also proposes that context sensitivity varies with the degree to which an item is linked to its context. However, in this case the link between cue and context is represented by the encoding of a third type of information, 'ensemble' information. The absence of this 'ensemble' information at test reduces the level of global activation and makes recognition more difficult. Thus, context-shift effects are smaller when 'ensemble' information is not created.

The above three theories all assume that recognition memory is a unitary process. However, there is mounting evidence to suggest that recognition can be better described by a dual-process theory (reviewed by Yonelinas, 2002). In dual-process models, recognition consists of two processes. First, one may have a feeling of 'familiarity' for a stimulus, 'knowing' that it has been encountered before. This indicates that the stimulus has been previously encountered, but does not necessarily include details of where, when or in what context. The second process is termed recollection, and involves 'remembering' a range of details about the previous occasion upon which the stimulus was encountered (Gardiner, 1988; Jacoby, 1991; Mandler 1980; Tulving, 1985). Recollection is thought to be hippocampally-dependent, whereas familiarity can be accomplished by extra-hippocampal mechanisms (reviewed by Aggleton & Brown, 1999). Dual-process models have close links to the two major theories of contextual memory, Conjunctive Representations Theory and Relational Memory Theory, making them a particularly attractive framework for studying contextual influences on memory retrieval (e.g., Norman & O'Reilly, 2003; Ranganath *et al*., 2003). Indeed, several behavioural and neural studies have found that context-shifts have different influences on recollection and familiarity, although the type of context changed is a crucial variable (e.g., Ecker *et al*.,, 2007b; Macken, 2002; Perfect, Mayes, Downes & van Eijk, 1996; though see McKenzie & Tiberghien, 2004; see Chapter 6 for extended discussion).

Although the models differ on many parameters, all propose that context-shift effects only occur when items are associated with their contexts in memory. Item-context associations may not be required for memory retrieval in a recognition memory task, because the target items are present during the test session, and so context-shift effects may be less apparent. In contrast to recognition memory, to succeed on a recall task the target items must be retrieved through links to aspects of the test context (including the instruction to retrieve given by the experimenter), accounting for the typically greater sensitivity of recall memory to a context-shift (e.g., Godden & Baddeley, 1975, 1980). Utilising both recall and recognition tasks when measuring contextual influences on memory in infancy is thus necessary to provide a broad picture of the role contextual information plays in memory retrieval.

1.9.3. Type of context and stimulus

The magnitude of a context change influences the magnitude of a context-shift effect. For example, Learmonth *et al.* (2004) found that 6-month-old infants showed impaired memory retrieval in a deferred imitation task when both the mat upon which they were seated, and the room in which they were tested, were different at encoding and retrieval. Changes to either the mat or the room alone had no effect on memory. The magnitude of a contextual change may partly be important because larger contextual changes produce larger changes in mood, which may be an important mediator of context-shift effects (e.g., Eich, 1995; Isarida & Isarida, 2004). A related idea is the theory that large contextual changes (such as moving from the lab to the participant's home) alter 'situational context', a shift in mindset that may be necessary for the production of significant context-change effects (Canas & Nelson, 1986).

The range of attributes included in the definition of 'context' is also influential. For example, Rovee-Collier, Schecter, Shyi and Shields (1992) explored the role of different contextual attributes in memory retrieval by manipulating the components of the crib liner that were altered between the training and test sessions for 6-month-old infants. Over a 24-hour delay, infants showed no evidence of memory retrieval when the shapes of the patterns on the liner were changed. However, a change in the colour of the patterns did not influence memory retrieval. Different types of contextual information also have different effects on memory retrieval in deferred imitation tasks. For example, in the puppet task, changes in intrinsic contextual information (the colour and form of the puppet) have a greater influence on memory for 12-month-old infants than changes in extrinsic contextual information (such as the room of testing; Hayne *et al.*, 2000).

Different modalities of extrinsic contextual information may also have different effects on memory retrieval. For example, for 3-month-old infants, changing a salient odour context between learning and retrieval has a greater influence on memory retrieval over a 24-hour delay than changing aspects of the auditory or visual context (Rubin, Fagen & Carroll, 1998; Schroers, Prigot & Fagan, 2007). Considering the elements included in the definition of 'context' is clearly important when interpreting developmental changes in the magnitude of context-shift effects.

In a recent meta-analysis of context-shift effects in human adults, Smith and Vela (2001) found that studies that included the experimenter amongst the contextual attributes that were changed between encoding and retrieval produced much larger context-shift effects than studies in which the same experimenter ran the demonstration and test sessions. Thus, social information may be particularly important in memory retrieval. However, no studies with adults have explored the influence of changing the experimenter alone, and the only studies to do so with infants have found mixed effects (e.g., Hanna & Meltzoff, 1993; Learmonth *et al.*, 2004; see Chapter 4 for discussion). The role of the experimenter in memory retrieval is an important area for further research.

Extrinsic context can also be divided into global and local features (Dalton, 1993), which have different effects on memory retrieval in adulthood. For example, Dalton (1993) found that changes to local stimuli (the name paired with a face) influence memory for familiar faces, whereas changes to global stimuli (the room in which testing took place) do not. Russo *et al.* (1999) replicated this result in a study with verbal stimuli. This finding is relevant to the interpretation of the results of Hartshorn *et al.* (1998b), in which local extrinsic context was changed for young infants, and global extrinsic context was changed for older infants (see section 1.8.2 for discussion). However, differences between global and local context may only be apparent when assessing memory retrieval for particular types of stimuli. Although Dalton (1993) and Russo *et al.* (1999) found that memory for familiar stimuli was influenced by changes in local but not global context, memory for unfamiliar stimuli was influenced by both changes. The authors argue that unfamiliar stimuli have been encountered in fewer environments, and so become more closely linked to the test environment (though see Reder *et al.*, 2006). Interestingly, Dalton (1993) obtained differences between familiar and unfamiliar stimuli on the basis of pre-exposure within the experiment. Considering the infant's history of experience with a stimulus may thus be an important variable to consider when assessing the magnitude of context-shift effects in infancy, in addition to considering the attributes included in the definition of 'context'.

1.9.4. The strength of memory for the target items

The 'outshining' hypothesis proposes that increasing the strength of the representation of a target item reduces the dependency of memory on contextual cues (Smith, 1988). This proposal has important implications for interpreting contextual influences on memory in infancy. Older infants tend to remember information for longer than younger infants (e.g., Barr & Hayne, 2000; Hartshorn *et al.*, 1998a), which may indicate that they possess a stronger representation of the target stimulus. If this leads to a concomitant decrease in the importance of contextual information in memory retrieval, this could partially account for age-related decreases in the influence of a contextual change on memory retrieval in infancy. Evaluating the conditions under which the outshining hypothesis provides an accurate description of context-shift effects is clearly important.

Several variables that reduce spontaneous forgetting also reduce the influence of a change in global extrinsic context on memory in rats. Millin and Riccio (2004) used a shock-avoidance paradigm to explore the effect of training and testing in two rooms differing in ambient lighting, noise, odour, and visual stimuli presented on the walls. Presenting rats with a pre-test 'reminder' with the reinforcer present during learning (a shock), increasing the number of training trials, or pre-test amphetamine administration (thought to improve memory) all reduced the magnitude of a context-shift effect over a 24-hour delay. Because all these manipulations also reduced spontaneous forgetting of the target information (the avoidance response), it is plausible that they strengthened memory for the target information, thus reducing mnemonic dependence on contextual congruency.

Research with adult humans also provides some evidence that increasing the strength of memory for target items reduces learning about contextual information, although it appears that effects are different for different types of context (e.g., Jurica & Shimamura, 1999; Mulligan, 2004). Memory for intrinsic contextual information (such as the colour of a word) may be reduced when item strength increases (Mulligan, 2004; Mulligan, Lozito & Rosner, 2006), but memory for local extrinsic contextual information (such as the colour of the background upon which the word is presented) is typically unaffected (Mulligan *et al.*, 2006). Furthermore, the effect of a change of local extrinsic context on memory for target items is unaffected by increases in item strength (Dougal & Rotello, 1999; Murnane & Phelps, 1995). However, the effect of a change of global extrinsic context (such as a change of room) on memory is reduced when item strength is increased (Smith, 1986). Thus, increasing item strength appears to reduce the influence of intrinsic and global extrinsic context on memory, but not local extrinsic context. Focussing on a target item does not have an equivalent effect on the processing of different types of contextual information.

Few investigations have directly explored the relationship between item strength and contextual influences on memory in human infants, but one study found that increasing the amount of training infants receive magnifies the effect of a change of intrinsic context (Fagen, Morrongiello, Rovee-Collier & Gekowski, 1984). Fagen *et al* (1984) found that 3-month-old infants responded to a novel mobile 24-hours after training if they had received one training session with the original mobile, but not if they had received two training sessions. Extra training with the same mobile increased the influence of an intrinsic contextual change on memory retrieval, a result that is congruent with the observation that infant rats, unlike adult rats, show increased contextual learning when given more exposure to the target items (Brasser & Spear, 2004). Thus, manipulating item strength may have different effects in infants than in adults. Exploring this question further with human infants may shed light on the extent to which age-related changes in the strength of target item encoding can explain age-related decreases in contextual influences on memory retrieval.

1.9.5. The relationship between target item and context

One of the most effective means of reducing context-shift effects in the mobile task has been the use of variability training (e.g., Amabile & Rovee-Collier, 1991; Boller & Rovee-Collier, 1992; Rovee-Collier & DuFault, 1991), a technique that is also effective with adults (e.g., Rothkopf, Fisher & Billington, 1982, Smith, 1982). In this procedure, participants are exposed to the target information in more than one context during the training session. For example, training 3- and 6-month-old infants in the presence of more than one crib liner enhances their responding in the presence of a novel crib liner (Amabile & Rovee-Collier, 1991; Rovee-Collier & DuFault, 1991). Similarly, when infants are trained with more than one mobile, they subsequently show evidence of memory retrieval with a novel mobile, a manipulation that would have precluded memory if infants had been trained with a single mobile (Amabile & Rovee-Collier, 1991; Boller & Rovee-Collier, 1992; Fagen *et al.*, 1984; Hayne, Rovee-Collier & Perris, 1987; Rovee-Collier, Borza, Adler & Boller, 1993). Indeed, mere exposure to the moving mobile in the presence of crib liner B after two training sessions with crib liner A enables infants to respond to the mobile in the presence of crib liner C 24-hours later (Boller & Rovee-Collier, 1992), and mere exposure to a second moving mobile is similarly effective at promoting generalisation to a novel mobile (Rovee-Collier *et al.*, 1993; Rovee-Collier, Adler & Borza, 1994). This confirms that variability training is not effective because infants only receive one training session with each specific mobile (Fagen *et al.*, 1984). Variability training thus reduces infants' reliance on contextual congruency at encoding and retrieval, although the success of this procedure in other infant memory paradigms, or with older infants, is unknown.

Variability training represents a manipulation of the relationship between the target response (leg kicking) and intrinsic or extrinsic contextual information (such as details of the training mobile, or the distinctive crib liner). When infants are trained with more than one mobile, the leg kicking response is paired with mobiles with different perceptual characteristics, reducing the predictive relationship between those characteristics of the mobile, and the target response. Item-context links may thus be disrupted by variability training, reducing the magnitude of contextual influences on memory retrieval. Variations in the degree to which a contextual attribute is predictive of target information may thus influence the magnitude of context-shift effects.

Directly encouraging adult participants to link items and their contexts can also increase the magnitude of context-shift effects (e.g., Baddeley, 1982; Eich, 1985; Mori & Graf, 1996; Schacter & Graf, 1986). For example, Mori and Graf (1996) found that when a picture was used as a contextual cue in a verbal learning study, larger context-shift effects were seen when participants were asked to generate a sentence linking the target word to the picture than when they were just asked to think about each word and picture. In contrast, increasing the strength of links between the stimuli used during the learning session (increased associative processing) may reduce the magnitude of context-shift effects (Smith and Vela, 2001). Associative processing may promote inter-item links in favour of item-context links. Interestingly, studies exploring individual differences have found that variations in the tendency to focus on the relationship between an object and its background may predict variations in context-shift effects (Chua, Boldan & Nisbett, 2005; Masuda & Nisbett, 2001; Masuda & Nisbett, 2006; reviewed by Nisbett, 2003; Smith, 1985). The magnitude of context-shift effects in infancy may thus be partly determined by the degree to which the relationship between objects and their backgrounds is processed and remembered.

1.9.6. Implications for the study of contextual memory in infancy

There are important developments in retrieving memory out-of-context around the second half of the first year of life (Hartshorn *et al.*, 1998b; Hayne *et al.*, 2000). Broadly, 12-month-old infants are more able to express their memories across a change in the experimental context than 6-month-old infants. However, little is known about the nature and extent of this change, partly because context has typically been defined in different ways in different paradigms, and memory has been tested over different relative retention intervals. Furthermore, infants have typically been tested at home, a highly familiar environment that cannot be controlled within and between studies. This makes it difficult to build up a coherent picture of the development of contextual memory in infancy.

Research with human infants, adult and animals indicates the variables that might be important to control or manipulate when studying contextual memory in infancy. When comparing the performance of infants of different ages, the use of short retention intervals is most appropriate for understanding age-related changes in contextual influences on memory retrieval. Contextual influences on memory vary with the type of memory task used, and the attributes included in the definition of 'context'. This means that it is important to explore the influence of different types of context on memory with a variety of measures. Exploring the factors that alter the magnitude of a context-shift effect, and the memory processes that are affected by a context-shift, will provide a detailed understanding of contextual influences on memory retrieval in different age groups.

1.10. Aims of the thesis

Developing a detailed understanding of contextual influences on memory retrieval in the infancy period is crucial for three reasons. First, it helps us to understand the range of situations in which infants can remember their previous experiences and use them to guide behaviour. Second, it helps us to map between behaviour and brain development with more precision. Third, it constrains and guides hypotheses about the underlying mechanisms of developmental changes in contextual memory. To these ends, the aim of this thesis was to build a more coherent picture of the developing role of context in memory retrieval in the second half of the first year of life.

A series of studies examined different aspects of contextual influences on memory retrieval in infancy. All were conducted over short retention intervals, to minimise potential confounds caused by age-related differences in rates of forgetting, and all were conducted in the laboratory, such that infants' experience with contextual information could be controlled. Two different paradigms were employed, because memory retrieval may be affected by contextual information to different extents when memory is measured in different ways.

More specifically, three questions were posed:

1.10.1. What is the influence of a change of physical and social context on infant memory retrieval? (Chapters 3 and 4)

Several forms of contextual information are particularly important to explore in infancy: the global extrinsic context of testing (such as the room in which testing occurs), the people present during testing (such as the experimenter), and salient local contextual cues (such as the background of a stimulus). These contextual features are important to explore for two reasons. First, infants might need to retrieve memory with a different person, in a different room, or when a toy is placed on a different background. Exploring the constraints social, global and local context exerts on memory retrieval reveals the extent to which they may be successful. Second, research with adults and animals reveals important distinctions between global and local context (e.g., Dalton, 1993), and between social and physical context (e.g., Smith & Vela, 2001), indicating that the effects of these types of context on memory in infancy should be studied separately. Experiments 1 and 2 explored developmental changes in the influence of a change of room on recognition memory, a question that has not been previously addressed with infants aged 6-months and older. Experiments 3 and 4 explored developmental changes in the influence of a change of distinctive background on recall memory, and developmental changes in the influence of a change of experimenter on recall and recognition memory, questions that have not been directly addressed in previous work.

1.10.2. What factors influence the effect of a change in intrinsic context on infant memory retrieval? (Chapter 5)

By 12-months, changes in social and physical extrinsic context have little effect on memory retrieval (Klein & Meltzoff, 1999). However, intrinsic contextual details, such as the form of a central stimulus, continue to exert strong control over memory retrieval (Hayne *et al.*, 2000). Any manipulations that promote generalisation across an intrinsic contextual change are therefore likely to exert a strong influence on memory retrieval. However, little is known about the factors that facilitate generalisation in 12-month-old infants. Identifying such manipulations might illuminate the processes governing contextual influences on memory retrieval in this age group. Experiments 5 and 6 thus explored the effect of a number of variables on generalisation across a form change in 12-month-old infants.

1.10.3. What processes underlie contextual influences on memory retrieval? (Chapter 6)

To determine the causes of developmental change in contextual influences on memory retrieval, it is necessary to understand the processes underlying context-shift effects. However, different memory processes have not been well specified in infants. Studies with adults can be used to provide insight into future areas of exploration with infant populations. Experiments 7, 8 and 9 explored the influence of a context-shift on two memory processes in adulthood: recollection and familiarity. Recollection and familiarity were chosen for their links to the two major theories of contextual memory (RMT and CRT), the degree of empirical support for the dissociation, and their links to cued recall and recognition memory tasks. In order to increase the relevance of the results to infant research, recollection and familiarity were assessed through their neural correlates using an electroencephalogram (EEG), because this method would be suitable for a comparable study with infants in the future. The context-shifts used represent those used earlier in Experiments 1 to 4 with infant populations (a change of room, and a change of background colour), which have not been previously studied in with EEG in adults, enabling the results to be used to inform hypotheses about the mechanisms underlying developmental change in infancy.

The next Chapter introduces the two paradigms that will be used to explore these questions with infants.

Chapter 2: Measuring memory in infancy

2.1. Introduction

The visual paired comparison paradigm (VPC) and the deferred imitation paradigm are particularly suitable for exploring contextual influences on memory retrieval in the infancy period. Both paradigms have a long history in the study of memory in infancy, providing a rich framework within which the results of the present studies can be interpreted. Both paradigms are suitable for 6- to 18-month-old infants, allowing the performance of different age groups to be directly compared under the same conditions. This is a particularly important age group to study, because there may be important changes in contextual memory have previously been observed across this age range (e.g., Hayne *et al.*, 2000; Robinson & Pascalis, 2004). Finally, the two paradigms assess memory in different ways, and so provide complementary evidence concerning the role of contextual information in memory retrieval in infancy. In the next sections, the VPC and deferred imitation paradigms are presented and discussed. Evidence is presented that both paradigms can be used to study contextual influences on memory retrieval. Finally, the limitations of each paradigm, and the motivation for using both paradigms in the following research, are explained.

2.2. The Visual Paired Comparison Paradigm

2.2.1. The paradigm and its history

The VPC was originally developed in response to two observations: that chimps distribute their attention unevenly between paired stimuli (Fantz, 1956), and that infants have a preference for novelty (Fantz, 1964). In the latter study, Fantz exposed 2-month-old infants to pairs of photographs for 1 minute, one of which was repeated in every presentation. On each successive presentation, the repeated photograph was paired with a novel photograph. Over time, infants increased their looking to the novel photograph in each pair. Taking these observations as his starting point, Fagan (1970) developed the VPC. There are many procedural variations of the VPC, but all share a basic common structure. The participant is first familiarised with a stimulus. During the subsequent test session, the participants are presented with the familiarisation stimulus and a novel stimulus, and the amount of time they spent looking at each stimulus is recorded. Inserting a delay between the familiarisation and test sessions allows researchers to use the VPC to measure memory. Assuming that in the absence of familiarisation the two stimuli are equally attractive, differential looking to the two stimuli is attributed to memory for the familiar stimulus.

Looking behaviour in the VPC was originally interpreted with reference to Solokov's (1963) neural model of the habituation of the orienting response. In this model, when a stimulus is novel, organisms quickly orient to it. Over time, the organism begins to form an internal representation of the stimulus. As the representation becomes more complete through continued attention, the stimulus becomes more familiar and the organism is less likely to orient to it until finally the organism no longer attends to the stimulus. According to Solokov's model, during the familiarisation phase of the VPC the participant initially builds an internal representation of the familiarisation stimulus. During the test phase, attention to the familiar stimulus is inhibited if the participant has retained this internal representation, leading to an increase in attention to the novel stimulus relative to the familiar stimulus (a novelty preference). By this logic, a novelty preference during the test session indicates memory for the familiarisation stimulus, and equal looking to both stimuli results when the familiar stimulus is forgotten. Since Fagan's original studies, many researchers have found novelty preferences in infant populations (e.g., Cohen, 1970; Diamond, 1995; Olson & Sherman, 1983; Pancratz & Cornell, 1974; Pascalis, de Haan, Nelson & de Schonen, 1998; Slater *et al.*, 1983). Indeed, from a few days of age infants show novelty preferences immediately or after a short delay (Pascalis *et al.*, 1998; Slater *et al.*, 1983).

2.2.2. What does the VPC measure?

One way to explore what the VPC can reveal about memory in infancy is to attempt to identify the 'type' of memory the VPC measures. Some memory classification systems were briefly reviewed in Chapter 1, including the distinction between declarative and non-declarative memory (reviewed by Squire, 2004). In Solokov's model, preferences are driven by habituation, a non-declarative form of memory. Other researchers have argued that the VPC taps other forms of non-declarative memory, such as operant conditioning (Malcuit *et al.*, 1988; Snyder, Blank & Marsolek, in press; though see Kuhn, 1989). In contrast, many other researchers have argued that novelty preferences are more likely to result from declarative memory for the familiar stimulus, making the VPC an analogue of an explicit recognition memory task (e.g., Hayne, 2004; Hunkin, Holdstock, Isaac & Mayes, 2004; Manns, Stark & Squire, 2000; McKee & Squire, 1993; Pascalis, Hunkin, Holdstock, Isaac, & Mayes, 2004).

One reason it may be difficult to conclude that the VPC (or indeed any test) taps a particular 'type' of memory is that performance on a particular task is seldom likely to be 'process-pure' (Jacoby, 1991). In other words, performance on most tasks can be driven by a number of different memory processes. In the case of the VPC, all these memory processes serve the same function; that is, to identify a perceptually present stimulus as being familiar (or unfamiliar). An alternative function of memory is to retrieve a piece of information that is not perceptually present, such as a previously observed action. These two functions of memory are associated with the terms 'recognition' and 'recall' respectively. When the target information is present, the participant has to 'recognise' the test stimulus. When the target information is absent, the participant has to 'recall' the test stimulus. In the VPC, the target information is present, and so the VPC falls within the class of tasks requiring 'recognition memory' (e.g Clark, Zola & Squire, 2000; Pascalis *et al.*, 2004; Robinson & Pascalis, 2004)[5].

2.2.3. Brain structures involved in VPC performance

The VPC paradigm is a versatile task that is suitable for use with both adult human (Manns *et al.*, 2000; McKee & Squire, 1993; Pascalis *et al.*, 2004; Richmond *et al.*, 2004) and animal populations (Bachevalier, Brickson & Hagger, 1993; Buffalo *et al.*, 1999); Pascalis & Bachevalier, 1999; Zola *et al.*, 2000), as well as for infants. Studies with adults and animals have enabled the exploration of the neural basis of VPC performance, which indicates what the VPC has the potential to reveal about brain function in infancy.

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[5] This use of the terms recognition and recall does not imply that the processes involved conscious awareness of retrieval.

In non-human primates, VPC performance depends on the integrity of the medial temporal lobe region (Bachevalier *et al.*, 1993; Buffalo *et al.*, 1999; Pascalis & Bachevalier, 1999; Zola *et al.*, 2000). For example, Bachevalier *et al.* (1993) found deficits in VPC performance in infant and adult monkeys with damage to the hippocampal formation, amygdala and surrounding tissue. Subsequent studies with more localised lesions also found deficits in VPC performance. Lesions of the hippocampal formation (Pascalis & Bachevalier, 1999; Zola *et al.*, 2000), the perirhinal cortex (Buffalo *et al.*, 1999), area TE of the inferior temporal cortex (Buffalo *et al.*, 1999), or area TH/TF of the parahippocampal gyrus (Nemanic, Alvarado & Bachevalier, 2004) all affect VPC performance over short delays. For example, Pascalis and Bachevalier (1999) used a VPC task with adult monkeys who had received aspiration lesions of the hippocampal formation at birth. Whereas control animals showed novelty preferences in the VPC after delays of up to 24 hours, lesioned animals only showed novelty preferences when tested after a 10-second delay. Nemanic *et al.* (2004) systematically compared the effects of ibotenic lesions of the hippocampal formation, aspiration lesions of the perirhinal cortex, and aspiration lesions of the parahippocampal cortex on VPC performance in adult monkeys. Hippocampal lesions impaired performance over a 60-second delay, perirhinal lesions impaired performance over a 10-second delay, and parahippocampal lesions impaired performance over a 30-second delay. Areas of the medial temporal lobe are crucial in VPC performance in both infant and adult monkeys, but in a delay-dependent manner.

Two studies have used the VPC paradigm with patients with temporal lobe amnesia to investigate the brain structures that underlie VPC performance in human adults (McKee & Squire, 1993; Pascalis *et al.*, 2004). McKee and Squire (1993) found that patients with damage to either the medial temporal lobe or the diencephalon show no evidence of recognition memory in the VPC over a retention interval of 1 hour, and showed a significant impairment compared to controls after a delay of just 2 minutes. Indeed, YR, a patient with bilateral hippocampal ablations, showed impaired VPC performance when tested immediately after the familiarisation period (Pascalis *et al.*, 2004). Thus, structures in the medial temporal lobe are also important for VPC performance in human adults, even when memory is tested over very short delays.

Performance on the VPC may be related to performance on explicit measures of recognition memory in adulthood. Explicit recognition memory tests require participants to consciously identify a familiar stimulus. For example, in a forced-choice recognition memory test participants may be given a familiar and a novel stimulus, and be asked to point to the one they saw during the learning session. In McKee and Squire's study, participants completed a forced-choice recognition memory test for the stimuli previously used in the VPC (McKee & Squire, 1993). Performance in the VPC was a small but significant predictor of performance in the forced-choice recognition memory task, a finding replicated with normal adults by Manns *et al.* (2000). However, though amnesic patients did not show a significant preference in the VPC after a retention interval of 1 hour, they showed above-chance performance on the forced-choice recognition memory task. Furthermore, YR performs at normal levels on an object recognition memory test over a 10-second delay, despite her marked impairment in performance on the VPC when tested immediately (Pascalis *et al.*, 2004). Thus, the VPC is not equivalent to an explicit forced-choice recognition memory measure, although performance on the two tasks may be related.

Medial temporal lobe structures clearly play an important role in recognition memory in the VPC, at least in adult human, and adult and infant non-human primate populations. This provides a tentative indication of the brain areas that might underlie performance on the VPC in human infancy, although this remains an empirical question. Nonetheless, there is some evidence that using the VPC to study infant memory may provide indirect evidence concerning the functioning of the medial temporal lobe region in infancy.

2.2.4. Longitudinal correlates of VPC performance

An alternative method of investigating what the VPC reveals about infant memory is to examine the longitudinal behavioural correlates of infant VPC performance. This indicates whether the VPC reflects a form of memory that is stable across long periods of development, and reveals which traditional memory tasks are most closely related to the VPC. In an initial exploration, Colombo, Mitchell, Dodd, Coldren & Horowitz, (1989) tested 16-month-old infants who had previously been tested with a VPC procedure at the age of 7-months on measures of spatial memory, exploratory behaviour and attention. In the spatial memory task, infants saw an experimenter hide an object under one of three cups. After a 15-second delay, the infant was allowed to retrieve the object. Only performance on this spatial memory procedure correlated with performance in the VPC at 7-months of age. The authors attribute this correlation to the fact that both procedures measure memory, and that "individual memory ability may ... contribute to the developmental continuity of early stimulus processing [VPC] tasks from infancy" (Colombo *et al.*, 1989, p 20).

Spatial memory is particularly reliant on the hippocampus (O'Keefe & Nadel, 1978). Indeed, place learning and object search tasks like that used by Columbo *et al.*, (1989) have been used with 18- to 24-month-old infants as an index of hippocampal functioning (Sluzenski, Newcombe & Satlow, 2004). Thus, the fact that performance in the VPC correlates with later spatial memory may reflect the fact that both require the hippocampus.

Other researchers have also found correlations between VPC performance in infancy, and measures of explicit memory in childhood (Rose, Feldman & Wallace, 1992; Thompson, Fagan & Fulker, 1991; though see Fagan, 1984). For example, Thompson *et al.* (1991) found that novelty preferences in the VPC task at 5- and 7- months of age correlated with scores on a picture recognition task at 3 years of age, even when IQ was accounted for ($r = 0.21$). Rose *et al.* (1992) found that novelty scores on a VPC battery at 12-months of age (but not 7-months) were correlated with a measure of picture recall at 6-years ($r = 0.24$), again after IQ was statistically controlled. In a follow-up study with the same children, novelty scores at 7-months of age (but not 12-months) correlated with a combined measure of recall and recognition at 11 years of age (Rose & Feldman, 1995). The correlations across these studies are remarkably consistent, despite variation in the ages at which children were tested, and the measures they were tested on. The memory processes tapped in the VPC in infancy may thus be related to those used to solve explicit recall and recognition tasks in later childhood, providing further evidence that the VPC provides a valid measure of infant memory.

2.2.5. Factors affecting performance in the VPC

Performance in the VPC is influenced by a number of variables, indicating that it provides a sensitive measure of memory. For example, increases in familiarisation time lead to greater novelty preferences (Fagan, 1974), although older infants require less familiarisation time to show significant novelty preferences than do younger infants (Morgan & Hayne, 2006; Richards, 1997; Rose, 1983). The amount of attention infants pay to the stimulus during familiarisation is also an important factor in determining their performance in the test (Richards, 1997). As is the case for most memory measures, performance in the VPC is affected by the interval between learning and retrieval. For example, the preferences infants show during the test session may change over time, with some studies showing novelty preferences over short retention intervals, and familiarity preferences (significantly longer looking at the familiar stimulus) over longer retention intervals, such as weeks or months (Bahrick & Pickens, 1995; Bahrick *et al.*, 1997; Courage & Howe, 1998, 2001; Jacobs, 2000). Finally, memory in the VPC is affected by the order in which stimuli are presented, with infants being more likely to show novelty preferences when tested with stimuli that were presented first or last in a list (e.g., Cornell & Bergstrom, 1983; Rose *et al.*, 2001). Memory retrieval in the VPC may be facilitated when representations of the familiarisation stimuli are stronger and easier to access.

2.2.6. Context-shift effects and the VPC

The sensitivity of the VPC to procedural variations indicates that the VPC might provide useful information about contextual influences on recognition memory in infancy. This can be explored by examining the effect of a context-shift on VPC performance. One group of infants is familiarised with a stimulus, then presented with the paired familiar and novel pictures according to the standard VPC procedure. A second group of infants receive the same familiarisation session, but are presented with the two test pictures in a different context. Context might be defined as the background upon which the pictures are presented, the room in which they are presented, or ambient music playing in the background during the testing procedure. The performance of infants tested in and out of the learning context is then compared, to assess whether the contextual change exerted any influence on recognition memory.

Several investigations using this logic show that the VPC is a useful paradigm for exploring context-shift effects in infancy (Haaf *et al.*, 1996; Pescara-Kovach, Fulkerson & Haaf, 2000; Robinson & Pascalis, 2004). For example, Haaf *et al.* (1996) explored the effect of a change of background pattern on recognition of a foreground object by using a VPC task with 6-month-old infants. Infants showed evidence of recognition when the objects were presented on the same backgrounds at encoding and retrieval, but no evidence of recognition when the background was changed. 6-month-old infants also fail to show recognition memory in a VPC procedure when ambient music that was played during familiarisation is absent or altered during the test session (Pescara-Kovach *et al.*, 2000). Taken together, these studies show that both auditory and visual contextual features influence recognition memory for 6-month-old infants.

These investigations confirm that the VPC paradigm is an appropriate technique for investigating contextual influences on memory retrieval in infancy. In the Introduction, three types of contextual information were identified that require further study: social information (such as the experimenter running the learning and test sessions), the global environment of learning (such as the room in which learning and testing sessions occur), and distinctive local cues (such as the background upon which a stimulus is presented). Research with the VPC has already provided valuable information about the role of local contextual cues in recognition memory in infancy (e.g., Haaf *et al.*, 1996; Robinson & Pascalis, 2004), suggesting that it may also provide valuable information about social and global contextual cues.

2.2.7. Limitations of the VPC procedure: Interpreting preferences

The major limitation of the VPC procedure lies in the interpretation of the patterns of preference infants display. Section 2.2.5 mentioned several studies in which infants showed preferences for the familiar stimulus in a VPC procedure, and these are not isolated results (reviewed by Houston-Price & Nakai, 2004; Pascalis & deHaan, 2001). If novelty preferences are taken as the only index of memory retrieval in the VPC, familiarity preferences may present a problem (Sophian, 1980).

The existence of familiarity preferences is certainly problematic for studies that use the VPC to explore infant reasoning or conceptual development, because conclusions are typically based on the assumption that infants only show novelty preferences (for discussion see Houston-Price & Nakai, 2004; Slater, 2004). However, familiarity preferences are less problematic when using the VPC to measure memory for a stimulus. Logically, both novelty and familiarity preferences represent discrimination between the test stimuli on the basis of their presentation history, and hence in either case it can be concluded that the infant is displaying evidence of recognition memory.

Furthermore, infants show a familiarity preference under a relatively restricted and predictable set of conditions (reviewed by Pascalis & de Haan, 2001). First, the nature of the stimulus influences the direction of preference. Infants may show a preference for familiar stimuli if they are biologically significant, such as a picture of their mother's face, though this effect may be age-dependent (Bushnell, Sai & Mullin, 1989; DeSchonen, Morton, Dereulle & Fabre-Grenet, 1995; Field, Cohen, Garcia, 1984; Pascalis *et al.*, 1995). Complex stimuli are also more likely to produce a familiarity preference (Hunter, Ross & Ames, 1982). Second, the time provided for familiarisation may affect the direction of the preference, with brief familiarisation times sometimes resulting in familiarity preferences (e.g., Hunter *et al.*, 1982; Richards, 1997; Rose, Gottfried, Melloy-Carminar & Bridger, 1982; Slater, 1995; Wagner & Sakovits, 1986; though see Lasky, 1980). For example, Rose *et al.* (1982) found that 3.5- and 6.5-month-old infants showed familiarity preferences for shape stimuli when familiarisation times were short (10 and 5 seconds respectively) but novelty preferences when familiarisation times were long (30 and 15 seconds respectively). Third, the retention interval between familiarisation and test sessions may affect preference direction, with familiarity preferences occasionally observed when the test occurs after long delays (e.g., Bahrick, Hernandez-Reif & Pickens, 1997; Bahrick & Pickens, 1995; Courage & Howe, 1998, 2001; Jacobs, 2000). For example, in Courage and Howe (1998), 3-month-old infants tested for recognition of a moving shape stimulus showed a novelty preference when tested after 1-minute or 1-day, a null preference after 1 week, a familiarity preference after 1-month, before a final null preference after 3-months.

Familiarity preferences may result from short exposure times or long retention intervals because a familiarity preference is obtained when there is only a partial match between the external stimulus and its corresponding internal representation (Bahrick &

Pickens, 1995; Hunter & Ames, 1988). When familiarisation times are brief, the infant may only have time to form a rudimentary representation of the familiarisation stimulus. If familiarisation times are sufficient for full encoding but retention is tested over a long delay, the representation may have become degraded or difficult to access. According to this model, both outcomes lead to the infant orienting to the familiar stimulus during the test session, in order to update their representation of the stimulus. Presumably, complex stimuli take longer to process, resulting in a less complete representation that also requires updating. Novelty preferences result when infants can retrieve an internal representation that fully matches the external stimulus (Spence, 1996).

Although this model is attractive and can account for a range of results, there are occasions upon which behaviour does not conform to the expected pattern (e.g., Lasky, 1980). Thus, controversy remains over the most appropriate theoretical explanation of the direction of the preference seen in a particular task (reviewed by Pascalis & de Haan, 2001). However, the theory that preferences emerge from the felicity of the match between an internal representation and the external stimulus (Bahrick & Pickens, 1995; Hunter & Ames, 1988) is the most complete and persuasive model currently available for interpreting preference direction, and so must be considered when examining preferences in a VPC procedure.

Null preferences (where infants show no significant preference for either stimulus) remain problematic to interpret, because it cannot be concluded that a null preference represents complete forgetting. In the example given earlier, 3-month-old infants showed a null preference after 1 week, but a familiarity preference after 1 month (Courage & Howe, 1998). In this case, the null preference did not indicate complete forgetting. The most parsimonious way of interpreting a null preference is that there is no evidence of memory for the familiar stimulus, but that it cannot be concluded that complete forgetting has occurred. However, this issue is not unique to the VPC. Indeed, in most memory tasks the absence of a response does not indicate complete forgetting, in the sense of irretrievable loss from memory. For example, in the mobile task, infants might fail to respond to the mobile immediately after a reminder treatment, but may show robust evidence of memory for the training contingency 24 hours later (Fagen & Rovee-

Collier, 1983). Presumably, the absence of responding to the mobile did not reflect the loss of memory for the training session, but its inaccessibility.

The VPC can provide valuable insight into the effect of a context change on recognition memory in infancy. However, there remain some limitations associated with this procedure. These can be offset by addressing similar questions with a different memory paradigm that uses a different means to assess memory. The deferred imitation paradigm provides a means to complement and extend research with the VPC, and this paradigm is discussed in the next section.

2.3. The Deferred Imitation paradigm

2.3.1. The paradigm and its history

Deferred imitation refers to the ability to reproduce an observed action from memory. For example, an infant may view his sibling pressing a button on a toy to produce music. Some time later, the infant may be allowed access to the toy. The infant could discover how the toy works for himself, through trial and error. Alternatively, and more expediently, the infant could learn to operate the toy by accessing his memory for his sibling's action, and reproducing it. This latter behaviour, the copying of previously observed actions after a delay, would be termed deferred imitation. Typically, 12- to 18-month-old infants learn one to two novel behaviours a day through observing and reproducing the actions of others (Barr & Hayne, 2003). Imitation is thus an important means by which infants learn new skills and behaviours.

The value of using deferred imitation to explore cognitive development was first highlighted by Piaget (1962). He argued that imitating a behaviour some time after it was observed requires the infant to encode and retrieve a mental representation of that behaviour, and use it to drive action. Thus, in order to demonstrate deferred imitation, infants must be able to remember the actions they saw performed. Using this logic, Meltzoff introduced a controlled experimental procedure that allowed researchers to use deferred imitation to investigate memory development (Meltzoff, 1985, 1988a,b). The procedure typically comprises two sessions. In the demonstration session, infants watch an experimenter perform one or several target actions with a stimulus. After a delay, infants are given the opportunity to interact with the stimulus, and the number of target actions that they reproduce is recorded. Memory is inferred if infants who have seen the demonstration session produce significantly more target actions than a control group of infants who did not see the target actions demonstrated.

There are several ways to design an appropriate control group, or 'baseline' condition (Meltzoff, 1985, 1988b). First, infants might not be exposed to the stimulus before the test session. However, the stimulus is then less familiar to the baseline group than to the experimental groups. Second, infants might be passively exposed to the static stimulus before the test session. This equates the familiarity of the stimulus between the baseline and demonstration groups, but does not equate the experience of observing an adult interacting with the stimulus. Third, in procedures in which the target actions lead to a salient outcome, such as a ringing bell, infants might be exposed to the adult holding the stimulus, and the sound of the ringing bell, but not to the target actions. This equates exposure to a potentially attention-grabbing feature of the demonstration session, and the experience of observing an adult interact with the stimulus, and thus provides the most conservative estimate of spontaneous performance.

The deferred imitation paradigm has several distinguishing features that differentiate it from similar tasks (for example, elicited imitation, e.g., Bauer, 1996; Bauer, Birch & Kleinknecht, 2002; Bauer & Mandler, 1989). First, the stimuli and actions chosen are novel to infants, often because they are specifically designed for the purpose of the experiment. Infants' experience with the stimuli and target actions can then be strictly controlled, so performance of the target actions can be more directly linked to experiences during the demonstration session. Typically, actions are chosen such that they are seldom (if ever) produced spontaneously by infants in the control group, confirming their novelty. Secondly, infants are not given the opportunity to interact with the stimuli at any point prior to the test session. The performance of actions during the test session then reflects a memory representation that was created through observation, rather than memory for a self-performed action. Thirdly, in a deferred imitation task the demonstration session is not narrated and the stimuli are not labelled. As infants of different ages have different degrees of verbal competence, it is important to ensure that apparent age-related improvements in deferred imitation are not actually driven by improvements in verbal understanding. However, even with novel stimuli and without practice or narration, infants show impressive memory capabilities. For example, 6- and 9-month-old infants exhibit imitation of actions demonstrated with objects over a 24-hour delay (Barr *et al.*, 1996; Collie & Hayne, 1999; Learmonth *et al.*, 2004; Meltzoff, 1988b), and by the age of 2 years infants can remember for up to 3 months (Herbert & Hayne, 2000a).

The effects of practice and narration may be particularly important to control when using deferred imitation to explore contextual influences on memory. When infants are tested with stimuli that are perceptually different but functionally similar to those used during the demonstration session, the infant must generalise across the intrinsic contextual changes in order to show evidence of memory retrieval. Nine- to 18-month-old infants generalise more readily in deferred imitation tests when they were allowed to practice the target actions during learning, suggesting that learning through observation and learning through physical experience may be controlled by different parameters (Herbert & Hayne, 2000b; Learmonth *et al.*, 2004). Six-month-old infants benefit less from practice (Learmonth *et al.*, 2004, 2005), indicating that there may be age-related changes in the effect of physical practice during learning. Similarly, verbal cues facilitate generalisation in some deferred imitation tests for 24-month-old infants but not 18-month-old infants (Herbert & Hayne, 2000b), suggesting that younger infants may benefit less from labelling or narration. Thus, the fact that deferred imitation tests are typically carried out in the absence of labelling or physical practice removes these factors as variables that might drive age-related changes in performance.

2.3.2. What do deferred imitation tasks measure?

As with the VPC paradigm, one can attempt to classify deferred imitation tasks as measures of a particular 'type' of memory. Many authors have argued that deferred imitation can be logically linked to declarative memory processes, providing the stimuli are novel and participants are not allowed to practice the actions before the test session (Jones & Herbert, 2006; Hayne, 2004; Mandler, 1990; Meltzoff, 1990; Piaget, 1962). Given these provisions, when an infant imitates after a delay he is demonstrating the ability to reproduce the actions of an event that is perceptually absent. This requires a mental representation of that event that persists over the retention interval, a key feature of declarative memory. However, the difficulty in designing any task that is 'process-pure' (Jacoby, 1991) also applies to deferred imitation tasks. Furthermore, it is often difficult to determine whether infants are remembering the actual event, or whether they simply remember the outcome of the action and reconstruct the action itself during the test session (for discussion see Want & Harris, 2002). Any difficulty in determining what infants are remembering makes it difficult to determine the 'type' of memory they are using.

Alternatively, the deferred imitation task can be classified in terms of the presence or absence of target information during the test phase. In deferred imitation tasks, neither the outcome of the target actions, nor the actions themselves, are perceptually present during the test phase. For example, a simple deferred imitation task may be to remove the hat from a toy pig (Knopf, Kraus & Kressley-Mba, 2006). During the test, the infant is presented with the pig with his hat placed on his head. In order to succeed, the infant must either remember that the hat can be removed, or that they saw the demonstrator remove the hat. The target information is perceptually absent during the test session, although the test object (in this case, the pig) provides a strong retrieval cue. For this reason, deferred imitation is often referred to as a 'recall' or 'cued recall' task (e.g., Bauer, 1996; Courage & Howe, 2004; Prudhomme, 2005).

2.3.3. Brain structures involved in deferred imitation

In human adults, imitation has been linked to a circuitry involving the superior temporal sulcus, the inferior frontal cortex, and the rostral part of the inferior parietal lobule (Decety *et al.*, 2002; Iacoboni *et al.*, 1999; Koski *et al.*, 2002, 2003; Nishitani & Hari, 2000). However, there have only been two studies examining the additional brain structures involved when a memory requirement is imposed, as is the case in a typical deferred imitation study. McDonough, Mandler, McKee and Squire (1995) tested seven adults with amnesia (three with damage to the hippocampal region) and three adults with frontal lobe damage on an age-appropriate version of the deferred imitation task. During the demonstration session, participants watched an adult model a sequence of actions with a set of stimuli. At the test session 24 hours later, participants were either instructed to recall the actions they had been shown, or simply given the stimuli without instruction. With or without instruction, both the patients with frontal-lobe damage and a group of neurologically normal age-matched adults performed significantly more of the target actions than a control group who had never seen the actions modelled. In contrast, the patients with amnesia, including those with hippocampal damage, did not produce significantly more actions than the control group, exhibiting no evidence of memory for the modelled sequence. The authors argue that this provides evidence that memory in the deferred imitation task is dependent on the integrity of the hippocampus and its connections.

A second study used the same task to explore deferred imitation in patients with developmental amnesia. Patients with developmental amnesia typically have bilateral hippocampal pathology incurred early in life as a result of a hypoxic-ischaemic episode, along with the possibility of some thalamic damage (Vargha-Khadem *et al.*,1997). Typically, patients have selective problems with remembering specific events (episodic memory), with the extent of the impairment being similar whether the damage occurred in infancy or in later childhood (Vargha-Khardem *et al.*, 2003). Adlam, Vargha-Khardem, Mishkin, & de Haan (2005) found that a group of patients with developmental amnesia associated with bilateral hippocampal volume reduction performed more poorly than a control group with no neurological damage on the deferred imitation task. However, unlike patients with temporal-lobe damage acquired in adulthood, patients with developmental amnesia showed some evidence of memory for the target actions. This may be due to the lack of damage to the perihippocampal region in the latter group, or it may be that plasticity of neural organisation in infancy allows some reorganisation of mnemonic function after the early insult (Nelson, 2000).

Neuropsychological studies provide some information about the brain structures necessary for deferred imitation in an adult population. However, it does not automatically follow that infants use the same brain structures as adults to succeed in deferred imitation tasks. One line of research has begun to tackle this question with a clinical population, Infants of Diabetic Mothers (IDMs). When a mother has diabetes during pregnancy, the infant is exposed to a variety of neurological risk factors including hypoxia, hyperglycemia and iron deficiency (Petry *et al.*,1992; Widness *et al.*, 1981). In animal models, these risk factors act selectively on certain brain regions, including the hippocampus (Barks, Sun, Malinak & Silverstein, 1995; de Ungria *et al.*, 2000). DeBoer, Wewerka, Bauer, Georgieff, & Nelson (2005) tested 29 twelve-month-old IDMs for deferred imitation of an action sequence with a 10-minute retention interval. The IDMs showed a subtle deficit in performance on the deferred imitation task in comparison to a group of age-matched control infants. This study thus provides some evidence that deferred imitation is sensitive to hippocampal damage in an infant population. However, as the presence of damage to the hippocampus was not directly verified by DeBoer and colleagues, this conclusion remains tentative. Nonetheless, there is some evidence that using deferred imitation tasks with infants may provide an indirect means of examining hippocampal functioning in infancy.

2.3.4 Longitudinal explorations

Although there are few longitudinal studies in this area, existing results indicate that there are stable individual differences in deferred imitation, and that these are related to individual differences in other social and cognitive abilities (Heimann & Meltzoff, 1996; Heimann *et al.*, 2006; Strid, Tjus, Smith, Meltzoff & Heimann, 2006). For example, an early study found a relationship between scores on a deferred imitation task at 9- and 14-months (Heimann & Meltzoff, 1996). Working with the same age groups, Heimann *et al.* (2006) found a relationship between deferred imitation at 9-months, and communication skills, including gestural communication and joint attention, at 14-months. In the short-term, deferred imitation is thus associated to other forms of social cognition. A follow-up study tested cognitive and linguistic abilities in the same children at age 4 years (Strid *et al.*, 2006). Infants who scored poorly on a combined measure of deferred imitation and joint attention in infancy also scored poorly on a measure of cognitive ability in childhood. There is thus some evidence that individual differences in deferred imitation in infancy are related to individual differences in cognitive skills in early childhood. However, more research is needed to establish the relationship between deferred imitation in infancy, and specific cognitive abilities in childhood.

2.3.5. Factors affecting performance on deferred imitation tasks

Performance on deferred imitation tasks is influenced by a number of variables, indicating that deferred imitation provides a sensitive measure of memory in infancy. For example, increasing the duration of the demonstration session increases the duration of infants' retention, but older infants require less encoding time than younger infants to show retention over the same delay (Barr *et al.*, 1996). Performance on deferred imitation tasks tends to decline as the interval between learning and test increases, although older infants tend to remember for longer than younger infants (Barr *et al.*, 1996; Klein & Meltzoff, 1999; Herbert & Hayne, 2000a). Finally, infants perform better on deferred imitation tasks when the actions they are shown follow each other in a logical sequence (such as placing a ball into a cup, then placing the lid onto the cup to form a rattle), than when the actions are arbitrarily ordered (Barr & Hayne, 1996; Bauer & Mandler, 1989,1992; Bauer & Thal, 1990; Mandler & McDonough, 1995). Memory retrieval in deferred imitation tasks is thus facilitated when representations of the demonstration session are stronger, more coherent, and easier to access.

2.3.6. Context-shift effects and the deferred imitation task

The sensitivity of deferred imitation to procedural variations indicates that this procedure might provide useful information about contextual influences on recall memory in infancy. As reviewed in Chapter 1, studies with deferred imitation tasks have demonstrated that recall memory is influenced by a change from home to the laboratory (Hayne *et al.*, 2000), and changes in intrinsic contextual information (perceptual details of the object upon which the target actions are performed; e.g., Hayne *et al.*, 1997). However, less is known about the roles of other types of context in memory retrieval in a deferred imitation paradigm. Since deferred imitation tasks have provided valuable information about the role of large changes in global environment on recall, they may provide valuable information about the role of local contextual cues, such as the background of a stimulus, and social context, such as the experimenter running the test session, in memory retrieval in infancy.

2.3.7. Limitations of the deferred imitation procedure

Deferred imitation tasks have two particularly important limitations. First, it may be difficult to determine whether infants fail to produce the actions they have learned because they have forgotten them, or because they are not motivated to imitate in the test setting. For example, Learmonth *et al.* (2005) argue that infants may fail to imitate in the presence of a stranger because of behavioural inhibition, a reluctance to act due to uncertainty in a novel situation. The possibility of behavioural inhibition could be examined by assessing the latency with which infants first touch the test stimulus after it is presented to them. If infants are equally quick to interact with the stimulus in all experimental conditions, performance is less likely to have been limited by behavioural inhibition in any particular condition.

Second, as mentioned in Section 2.3.2, performance in a deferred imitation task may sometimes be supported by processes other than imitation (e.g., Huang & Charman, 2005; Huang, Heyes & Charman, 2002; Thompson & Russell, 2004; Tomasello, 1990; Tomasello & Call, 1997; Want & Harris, 2002). For example, 'stimulus enhancement' occurs when a participant's attention is drawn to a certain stimulus as a result of observing another's interest in it. Although this can be ruled out by the use of appropriate control groups, other possibilities are more difficult to exclude. Participants may, for example, succeed in a deferred imitation task by learning the goal or outcome of an action, and reproducing it at a later date (Thompson & Russell, 2004). This has been termed 'goal emulation', and does not involve retrieving memory for the action sequence that led to the goal (Tomasello, 1990). This means that it can be difficult to determine the precise socio-cognitive processes involved in deferred imitation tasks. When using imitation to study memory, this problem is less pressing than when trying to determine whether a particular species can or cannot imitate. Goal emulation after a delay requires the infant to remember the person's goal, and reproduce it. Thus, however infants solve an imitation task, memory is required for the solution to be produced after a delay at a higher frequency in the demonstration than the control groups. However, different versions of deferred imitation tasks may load on slightly different cognitive processes, raising potential difficulties in comparing results across studies using different procedures. For this reason, the deferred imitation task used in the present studies (explained in detail in Chapter 4) is one used frequently in published investigations (e.g., Barr *et al.,* 1996; Hayne *et al.*, 2000; Learmonth *et al.*, 2004, 2005). The baseline condition chosen matched that used in these studies, and represents the third (conservative) option of the possibilities outlined in Section 2.3.1.

2.4. Why use both tasks?

Both the VPC and deferred imitation tasks have been widely used to study memory in infancy (reviewed by Hayne, 2004; Rose, Feldman & Jankowski, 2004). This has provided a wealth of knowledge about the brain structures involved in performance, the factors controlling memory retrieval, and the strengths and limitations of each procedure. This enables investigations with these procedures to be designed and interpreted with reference to a rich empirical and theoretical literature. Both VPC and deferred imitation tasks have been found to be sensitive to context-shift effects in an infant population (e.g., Haaf *et al.*, 1996; Hayne *et al.,* 2000), underlining their potential to provide useful information about contextual influences on memory retrieval. Furthermore, it seems that there may be age-related changes in the influence of a context-shift on memory retrieval in these tasks between the ages of 6- and 18-months (e.g., Hayne *et al.*, 2000; Robinson & Pascalis, 2004), confirming that both paradigms might provide important information about developmental changes in memory.

Despite these similarities, there are important differences between the VPC and deferred imitation tasks, indicating the importance of using both to assess contextual influences on memory retrieval. On the basis of the information presented during the test session, the VPC can be regarded as a visual recognition memory task, and the deferred imitation paradigm provides a nonverbal analogue of a cued recall task. Research with adults reveals that the presence or absence of target information during the test session may have an important influence on the degree to which memory is affected by a context-shift (e.g., Godden & Baddeley, 1975, 1980), and so it is important to explore contextual influences on memory in infancy with both recall and recognition measures. Furthermore, recognition and recall represent two important ways through which infants might use memory – to identify something that has been seen before, and to remember its function. Using both the VPC and deferred imitation tasks to explore the factors controlling memory retrieval in infancy thus allows us to build a broad picture of the range of situations in which infants can retrieve their memories, and the factors controlling this ability for different age groups.

The remainder of the thesis presents a series of experiments designed to develop understanding of the role of contextual information in memory retrieval in infancy, and how it might change across development, through exploring the topics identified at the end of Chapter 1. The precise method used to address particular questions is discussed and justified for each experiment in turn, but all infant studies use either a deferred imitation task, or a VPC task, or both, depending on the approach deemed most informative for each question. Through using multiple paradigms, the present studies provide converging evidence on the role of contextual information in infant memory retrieval.

Chapter 3: The effect of a change of global context on recognition memory in 6- to 18-month-old infants

3.1. Introduction

The aim of the experiments presented in this Chapter was to explore the effect of a global context change on memory in infancy.

3.1.1. Global context in deferred imitation and operant conditioning paradigms

In operant conditioning procedures, 6-month-old infants show no evidence of memory retrieval when the training and testing sessions occur in different rooms in their home over a 24-hour delay (Hartshorn *et al.*, 1997). However, 9- and 12-month-old infants are unaffected by a room change over this delay, although over much longer delays (42-days for 9-month-olds, and 56-days for 12-month-olds) memory is again context-specific (Hartshorn *et al.*, 1998b). Such age-related changes in contextual influences on memory retrieval are also seen in deferred imitation tasks (e.g., Hayne *et al.,* 2000; Learmonth *et al.*, 2004). For example, memory retrieval is precluded for 6-month-old infants over a 24-hour delay when learning occurs at home and test in the laboratory (Hayne *et al.*, 2000). However, for infants of 9-months and older, memory retrieval is typically unaffected by a change of global context in deferred imitation tasks (Herbert, Gross & Hayne, 2007; Hanna & Meltzoff, 1993; Hayne *et al.*, 2000), even over a delay of up to 4-weeks (Klein & Meltzoff, 1999).

However, the same change of context does not always have the same effect on memory retrieval in operant conditioning and deferred imitation paradigms. For example, for 6-month-old infants, when learning and retrieval are separated by 24-hours, a move from one room to another in the home has no effect on cued recall in a deferred imitation task (Hayne *et al.*, 2000; Learmonth *et al.*, 2004), but precludes retrieval in two operant conditioning procedures (Hartshorn *et al.*, 1997). The fact that the same change over the same retention interval has different effects on cued recall and operant conditioning measures of memory confirms the need to explore contextual influences on memory retrieval across the range of ways infants access their memories. Recognition memory may be particularly important to explore, because performance on recognition memory tasks is affected differently by a change of context in adulthood than is performance on other measures, such as recall (Fernandez & Glenberg, 1985; Godden & Baddeley, 1975, 1980; Smith *et al.*, 1978). Furthermore, recognition memory can be measured in a similar way in adults, infants and animals (e.g., Richmond *et al.*, 2004; Pascalis & Bachevalier, 1999), creating the possibility for closer research integration.

3.1.2. Global context in infant memory: Recognition measures

Only one study has explored the effect of a change of global context on recognition memory in infancy. Bushnell, McCutcheon, Sinclair & Tweedlie (1984) gave 5- and 9-week-old infants extensive familiarisation with shapes of different colours and forms. One day after the last familiarisation session, infants were presented simultaneously with a familiar stimulus and a novel stimulus. The novel stimulus differed from the familiar stimulus in its colour, in its form, or in both colour and form. The authors reasoned that the test may be 'easier' when the novel stimulus differed on two dimensions from the familiar stimulus, than when it differed on one. When familiarisation and test sessions both occurred in the infants' home, infants showed evidence of recognition memory in all three conditions. When familiarisation occurred in the infant's home and testing occurred in the laboratory, infants did not show evidence of recognition when given stimuli differing on only one dimension. However, when the novel and familiar stimuli differed in both form and colour, both 5- and 9-week-old infants <u>were</u> able to recognise the familiar stimulus. After an extensive period of learning, 5- and 9-week-old infants show a limited ability to recognise a stimulus across a change in global context.

3.1.3 The present study

Bushnell and colleagues found that recognition memory is influenced by details of the global context of learning in very young infants. In the light of evidence from operant conditioning paradigms and deferred imitation tasks demonstrating that 6-month-old infants are more influenced by a change of global context than 9- to 18-month-old infants (Hartshorn *et al.*, 1998b; Hayne *et al.*, 2000), it is important to explore how recognition memory in infancy is influenced by changes in global context over this age range. In the present study, a VPC task was used to explore whether a shift of global context influences recognition memory for 6- to 18-month-old infants, and whether there are age-related changes in the extent of any influence observed. Less extensive familiarisation was used than that employed by Bushnell *et al.* (1984), in line with most other studies that have used the VPC to explore context-shift effects (e.g., Haaf *et al.*, 1996; Robinson & Pascalis, 2004). Because a shorter familiarisation period is likely to make the task harder, the present procedure should make any context-shift effects easier to detect.

To allow age-related changes to be investigated whilst minimising the potentially confounding influence of age-related changes in forgetting (reviewed by Hayne, 2004), memory was tested over a short delay. A delay of 1 minute was chosen as it is considered sufficient to exceed the duration of working memory (Diamond, 1990). The change of global context employed was a change in location from one room in the laboratory to another. A change of room in the laboratory allows the appearance and familiarity of the testing context to be carefully standardised for different infants and different age groups. Furthermore, this manipulation has been used many times with adults, with both traditional recognition memory procedures (Dalton, 1993; Smith & Vela, 1992; Russo *et al.*, 1999) and an age-appropriate version of the VPC (Richmond *et al.*, 2004), enabling the present results to be more comparable with those from similar studies with adults.

The study was divided into two experiments, each with different age groups (6- and 9-month-old infants in Experiment 1, and 12- and 18-month-old infants in Experiment 2), because age-related changes in encoding speed mean that different familiarisation times may be appropriate for infants of different ages. These particular age groups were chosen because their memory retrieval has been well-studied with other paradigms (e.g., Hartshorn *et al.*, 1997, 1998b; Hayne *et al.*, 2000; Learmonth *et al.*, 2004, 2005), enabling the present results to be integrated with a body of knowledge of memory in infancy.

3.2. Experiment 1: 6- and 9-month-old infants

3.2.1. Experiment 1a: The effect of a room change

Previous work has found age-related decreases in the influence of a change in global context between 6- and 9-months on a deferred imitation procedure (Herbert, *et al.*, 2007). The present study examined the role of global contextual cues in recognition memory for these age groups.

3.2.1.1. Participants

Twenty-four 6-month-old (12 male) and twenty-four 9-month-old infants (12 male) were recruited from a database of infants born at the Jessop's Maternity Ward of the Hallamshire Hospital, Sheffield. Infants were tested within ten days of their 6- or 9-month birthday. No infant was born more than 3 weeks premature, and no infant had experienced birth complications. Testing was discontinued on 9 additional infants who were excessively fussy or cried during testing (two 6-month-olds and one 9-month-old), exhibited side bias (defined as looking at one of the stimuli for less than 5% of a test presentation; three 6-month-olds and two 9-month-olds), or due to experimenter error (one 9-month-old infant). These criteria are those used in other published studies, and the attrition rate is commensurate with that work (e.g., Robinson & Pascalis, 2004). Infants were Caucasian (n = 44), Asian (n= 2) and Afro-Caribbean (n = 2). The study, and all subsequent studies reported here were approved by the Department of Psychology ethical committee.

3.2.1.2. Apparatus and stimuli

Testing was conducted in two rooms, which served as the two contexts. The two rooms differed on many parameters, although the colour of the background upon which the stimuli were presented remained constant. Furthermore, both rooms were adjacent to each other on a short corridor, so the context experienced en route to each testing room was the same. Room A was a warm, soundproof chamber with walls covered in dark fabric. The room was divided in two by a partition. Into the partition was set a screen (46 cm x 32 cm), onto which the stimuli were back-projected during the VPC procedure.

Infants viewed this screen from a distance of approximately 60 cm whilst seated on their parents lap on one side of the partition. This section of the room was 3 m long by 1.24 m wide.

Room B was a more typical University Room. It was cooler in temperature than Room A, and the walls were painted pale lemon. Again, the room was split by a partition, which was covered in black material. On one side of the partition, the infant was seated on their parent's lap facing a trio of computer screens placed on a table covered in black material in front of the wall. This section of the room was 2.33 m long and 1.52 m wide. The computer screens were located approximately 60 cm in front of the infant.

In both rooms, the testing equipment was located on the opposite side of the partition to that on which the infant was seated, and during the VPC procedure the experimenter controlled the presentation of the stimuli on the monitors via a key board. A TV screen and video recorder were connected to a camera pointed to the other side of the partition, where the infant was seated. Thus, the experimenter could observe and record the infant's behaviour during the VPC procedure, but the infant was unable to see the experimenter.

The stimuli were colour photographs of adult human faces, approximately 10cm by 10cm in size (in both Rooms), presented on a plain black background. Two sets of faces were used (one pair of male faces, and one pair of female faces), to ensure that findings were not stimulus-specific. Each face in a set served equally often as the familiar or novel stimulus to ensure that effects could not be attributed to an existing preference for one of the stimuli, resulting in four different stimulus conditions. Stimuli were chosen to be highly discriminable and roughly equal in attractiveness, with different hair colour, hair cut and eye colour (see Figure 3.1). Infants were randomly assigned to one of the four sets, with the constraint that the gender of the infant and that of the stimuli were counterbalanced.

Figure 3.1. Examples of the face stimuli used in Experiments 1a, 1b and 1c (not actual size).

Faces were used for two reasons. First, from birth infants are known to be attracted by faces (reviewed by Slater & Quinn, 2001), making it likely that infants will attend to the stimuli during the learning phase (e.g., Rose, 1981). Second, research with adults on context-shift effects has often used faces as stimuli (e.g., Dalton, 1993; Richmond *et al.*, 2004; Russo *et al.*, 1999; Smith & Vela, 1992). For example, adults' memory for faces in the VPC over a 2-week delay is affected by a change from one room to another (Richmond *et al.*, 2004). Using faces in the present study allows us stronger parallels to be drawn with research with adults.

3.2.1.3. Procedure

Each infant participated in one VPC test, consisting of a familiarisation and a test session. The sessions were separated by a 1-minute retention interval. Infants were randomly assigned to either the *Same Room* or the *Different Room* condition, with the constraint that within each age group there were equal numbers of male and female infants in each condition. Infants in the *Same Room* condition received both familiarisation and test sessions in the same room, and were randomly assigned to either Room A or B. Infants in the *Different Room* condition received familiarisation in one room and the test in the other room, and were randomly assigned to familiarisation in Room A and test in Room B, or vice versa.

3.2.1.3.1. Pre-test session

On arrival to the lab, caregivers and their infants were taken to a reception area where details of the study were explained, and consent was sought. The reception area was situated approximately 30 m down the corridor from Rooms A and B. This session lasted approximately 5 minutes.

3.2.1.3.2. The familiarisation session

After the pre-test session, infants were taken to either Room A or Room B to begin the familiarisation session. When the infant was settled on their parent's lap on the test chair, the light in the room was switched off and the session began. Approximately 30-40 seconds elapsed between entering the room and the start of the familiarisation session. In the familiarisation session, infants were presented with a single image until they had accumulated a fixed amount of looking time to the picture. Fixed-time habituation was used to produce comparability with tests of recognition memory with adults, in which stimuli are typically presented for fixed durations during the learning session (e.g., Dalton, 1993), and with other infant memory paradigms in which the learning session is of a set duration (e.g., Barr *et al.*, 1996; Shields & Rovee-Collier, 1992). Six- and 9-month-old infants received 20 seconds of familiarisation time (Robinson & Pascalis, 2004; Rose, 1981). Fixation was assessed online by the experimenter, and confirmed offline from a video-recording of the infant's eye movements.

3.2.1.3.3. The retention interval

At the end of the familiarisation session, the room light was switched on. For infants in the *Same Room* condition, during the 1-minute retention interval, the chair upon which the parent and infant were seated was turned away from the screen, and the experimenter interacted with the parent and infant. Infants in the *Different Room* condition were taken a short distance from one testing room to the other, and settled on their parent's lap in the second room. The experimenter interacted with the parent and infant during this period. After the 1-minute delay had elapsed, the test session began for infants in both conditions.

3.2.1.3.4. The test session

At the start of the test session, the room lights were turned off. Infants were presented with two 5-second recognition tests in which the familiarisation image was presented alongside a novel stimulus. In the second test, the lateral position of the images was reversed. The initial lateral positions of the stimuli were counterbalanced between infants. Infants' eye movements were recorded on a video for later analysis.

3.2.1.5. Results and Discussion

Looking times to the novel and familiar images were calculated offline by frame-by-frame analysis of the video recordings. A second observer coded 50% of the video recordings; inter-observer reliability was 96%.

Looking times were totalled across both test periods, to examine whether the groups showed any differences in overall looking time to the test stimuli (Table 3.1). An Age (6- or 9-months) x Condition (*Same Room* or *Different Room*) ANOVA on total looking times revealed no significant main effects, and no significant interaction (all $p > 0.05$). This confirmed that infants in all groups viewed the test stimuli for comparable lengths of time.

Experiment	*Familiarisation time (s)*	*Age (months)*	*Mean Total Looking Time (s)*	
			Same Room	*Different Room*
1a	20	6	8.79 (0.42)	8.81 (0.28)
	20	9	8.44 (0.21)	8.81 (0.24)
1b	20	9 (Room Disruption)	8.48 (0.32)	n/a

Table 3.1. Total looking times to the test stimuli in Experiment 1.
The mean total looking time of groups of infants (n=12 per group) to the test stimuli in the *Same Room* and *Different Room* conditions. Standard errors are shown in parentheses. There were no significant effects of age or condition.

The predominant measure of memory in the VPC is the novelty score (Rose *et al.*, 2004), which equals the proportion of time infants spend looking at the novel stimulus relative to the familiar stimulus during the test session (Rose & Feldman, 1990; Fagan, 1974). Novelty scores are used to assess whether the distribution of looking differs from that expected by chance (a novelty score of 0.5). Novelty scores that are significant different to chance are taken to indicate recognition memory for the familiar stimulus.

Table 3.2 shows novelty scores for each group of infants in Experiments 1 and 2. Preliminary analyses indicated that novelty scores were not significantly affected by picture set, the particular room in which the test session was carried out, or the gender of the infant (all $p > 0.05$). The data were thus collapsed across these variables.

Experiment	*Familiarisation time (s)*	*Age (months)*	*Mean Novelty Score*	
			Same Room	*Different Room*
1a	20	6	0.60 (0.01) *	0.54 (0.03)
	20	9	0.57 (0.02) *	0.49 (0.03)
1b	20	9 (Room Disruption)	0.55 (0.02) *	n/a

Table 3.2. The effect of a change of room on recognition memory in 6- and 9-month-old infants. Mean novelty scores (by groups of infants ($n=12$ per group) in the Same Room and Different Room conditions of Experiments 1. Standard errors are shown in parentheses. An asterix indicates that preferences were significantly different ($p < 0.05$) to chance performance (0.5).

A two-way Analysis of Variance (ANOVA) on Age (6-months or 9-months) by Condition (*Same Room* or *Different Room*) was conducted on novelty scores. There was a significant main effect of Condition ($F(1, 48) = 7.385, p = 0.009$), indicating that infants showed significantly greater novelty scores in the *Same Room* condition than in the *Different Room* condition. No other effects reached significance.

Although an ANOVA reveals group differences, it does not indicate which groups of infants showed preferences that differed significantly from chance. Two-tailed one-sample t-tests were used to compare the percentage fixation to the novel stimulus to the chance level of responding (0.5). Infants in both age groups showed significant novelty preferences in the *Same Room* condition (6 month-olds: $t\ (11) = 12.262, p < 0.001$; 9-month-olds: $t\ (11) = 3.746, p = 0.003$). Thus, both 6- and 9-month-old infants showed evidence of recognition memory over a 1-minute delay when familiarisation and test occurred in the same location,.

In contrast, 6- and 9-month-old infants in the *Different Room* condition did not show a distribution of looking that was significantly different from chance levels (6-month-olds: $t(11) = 1.210$, *n.s.*; 9-month-olds: $t(11) = 0.382$, *n.s.*). It is unlikely that behavioural inhibition in the novel context could account for these results, as there was no significant difference between the total time infants spent looking at the test pictures in the *Same Room* and *Different Room* conditions in these age-groups (6-month-olds: $t\ (22) = 0.031$, *n.s.*; 9-month-olds: $t\ (22) = 1.177$, *n.s.*). Thus, when familiarisation and test sessions occurred in different locations, 6- and 9-month-old infants showed no evidence of recognition memory over a 1-minute delay.

Is it possible that infants were influenced not by the difference between the learning and testing rooms per se, but by the disruption of moving rooms between the familiarisation and test sessions? In the *Same Room* condition, infants remained seated with their parents in the testing room throughout the retention interval. In contrast, infants in the *Different Room* condition left one room, were carried down a corridor, and were settled in a second room. Winocur and Kinsbourne (1978) found that leaving the room of learning has an equivalent effect to a change of context on memory retrieval in a group of patients with Korsakoff's amnesia. Experiment 1b tested whether leaving the experimental room between learning and retrieval impacts on recognition memory in the VPC by testing a group of infants in a *Room Disruption* condition. In this condition, infants received the familiarisation and test sessions in the same location (as in the *Same Room* condition), but during the retention interval left the room and returned (as in the *Different Room* condition).

Since the 6- and 9-month-old infants did not perform significantly differently in Experiment 1a, only 9-month-olds were tested in Experiment 1b. Nine-month-old infants were chosen because previous evidence suggests that they show memory retrieval across a global contextual change when memory is measured with in other paradigms (e.g., Herbert *et al.*, 2007). The lack of generalisation shown by 9-month-olds in Experiment 1a is thus less congruent with previous research than for 6-month-olds, who show no evidence of memory retrieval in an alternate environment in a range of procedures (e.g., Hayne et al., 2000; Hartshorn et al., 1998a).

3.2.2. Experiment 1b: Room disruption

3.2.2.1. Participants

Twelve 9-month-old infants were recruited as in Experiment 1a. Testing was discontinued on 3 additional infants who were excessively fussy or cried during testing (n=1), or exhibited side bias during the test session (n= 2). Infants were all Caucasian.

3.2.2.2. Apparatus, stimuli and procedure

These was identical to that used for infants in the *Same Room* condition in Experiment 1a, except that each infant, their parent, and the experimenter left the room used for the familiarisation and testing session during the retention interval (*Room Disruption*).

3.2.2.3. Results and Discussion

Data were analysed as in Experiment 1a. Infants in the Room Disruption condition looked at the test pictures for a mean time of 8.47s (SE = 0.32s), which is comparable with looking times in Experiment 1a (see Table 3.1 for comparison).

Given the small number of participants, and Experiment 1a's findings that the gender of the infant, the particular experimenter who ran the demonstration or test sessions, and the particular background used during the test session did not affect performance, these variables were not analysed in the present Experiment.

Nine-month-old infants in the *Room Disruption* condition showed a mean novelty score of 0.55 (SE = 0.02), which was significantly greater than chance (t (11) =2.386, p= 0.038) and not significantly different from the mean novelty score of 9-month-old infants in the *Same Room* condition in Experiment 1a (t (21) = 0.851, *n.s.*). Thus, the failure of 9-month-old infants to exhibit recognition memory across a room change between familiarisation and test cannot be accounted for by the potentially disruptive effects of moving location during the retention interval.

3.2.3. Discussion of Experiment 1

Why did 6- and 9-month-old infants show no evidence of recognition memory in the *Different Room* condition in Experiment 1a? Behavioural inhibition in a novel context is insufficient to explain the present pattern of results, as total looking times did not differ between the *Same Room* and *Different Room* condition. Further, testing in a different context influences memory retrieval in other paradigms when infants are tested in highly familiar contexts (e.g., Learmonth *et al.*, 2004; Hartshorn *et al.*, 1998b), suggesting that mechanisms other than behavioural inhibition are involved.

Could the shift in context have altered the appearance of the stimuli, such that effects were not due to changes in the global context, but to alterations in the appearance of the stimulus itself? It seems unlikely. First, the size, brightness and colour of the stimuli were the same for infants in both conditions. Second, during the test session the lighting in both rooms was provided by the stimuli themselves, so the luminance in which they were presented was equivalent. Finally, other research with visual habituation tasks suggests that changes in the stimulus do not have a particularly disruptive effect on recognition (Cohen & Strauss, 1979; Fagan, 1976). For example, Fagan (1976) tested 29-week old infants in a habituation paradigm, and found them able to recognise a face stimulus when it was presented in a different orientation during the familiarisation and test sessions. In the present study, it is more likely that the large change in global context produced the observed effects on recognition memory, rather than any very minor changes in the appearance of the stimuli themselves.

Rather, the results suggest that both 6- and 9-month-old infants encoded details of the context of learning into their memory during the familiarisation session, and the disparity between the contents of memory and the external context during the test session led to a retrieval failure. The pattern of results seen with 6-month-old infants fits well with previous data showing that for this age group, memory retrieval in an operant conditioning task is influenced by a shift from one room to another at home (Hartshorn *et al.*, 1998b), and memory retrieval in a deferred imitation task is affected by a move from home to the laboratory (Hayne *et al.*, 2000). Thus, there is strong evidence that 6-month-old infants are heavily influenced by the congruency of the context at learning and retrieval. However, in previous studies with other paradigms, 9-month-old infants have shown evidence of memory retrieval when learning and test sessions occur in different global contexts at all but the longest retention intervals (Hartshorn *et al.*, 1998b; Herbert, *et al.*, 2007). In the present study, 9-month-old infants (like 6-month-old infants) showed no evidence of recognition memory over a short retention interval when learning and retrieval occurred in different locations. In order to identify the age at which infants start to show evidence of recognition memory across a change in context, Experiment 2 explored whether memory retrieval in 12- and 18-month-old infants is affected by a change of global context. These age groups were chosen because they have shown evidence of memory retrieval out of the learning context in other paradigms (Hartshorn *et al.*, 1998b; Hayne *et al.*, 2000).

3.3. Experiment 2: 12- and 18-month-old infants

As older infants typically process information faster than younger infants, age-appropriate familiarisation times may be required when using VPC procedures (e.g., Robinson & Pascalis, 2004; Rose, 1983), just as age-appropriate learning times are used in other paradigms (Hartshorn *et al.*, 1997, 1998b; Hayne *et al.*, 2000). However, employing different familiarisation times with different age groups means that any differences between age groups could due to systematic differences in their exposure to the target stimulus, or indeed to the learning context. The present study thus explored the effect of a change of context on recognition memory in 12- and 18-month-old infants, both when they received the same familiarisation time as the 6- and 9-month-old infants in Experiment 1 (Experiment 2a), and when they received an age-appropriate 10-second familiarisation period (Experiment 2b).

3.3.1. Experiment 2a: 20 seconds of familiarisation

3.3.1.1. Participants

Twenty-four 12-month-old infants and twenty-four 18-month-old infants were recruited in the same way as for Experiment 1a. Testing was discontinued on 11 additional infants who were excessively fussy or cried during testing (three 12-month-olds and two 18-month-olds), failed to look at the test pictures for long enough (one 12-month-old and two 18-month-olds), exhibited side bias during the test session (two 12-month-olds), or due to experimenter error (one 18-month-old). Infants were all Caucasian and from families of moderate to high socio-economic status.

3.3.1.2. Apparatus, stimuli and procedure

These were identical to those used in Experiment 1a.

3.3.1.3. Results and Discussion

Data were analysed as in Experiment 1. Looking times were then totalled across both test periods, to examine whether the groups showed any differences in overall looking time to the test stimuli (Table 3.3). An Age (12- or 18-months) x Condition (*Same Room* or *Different Room*) ANOVA on total looking times revealed no significant main effects, and no significant interaction. This confirmed that infants in all groups viewed the test stimuli for comparable lengths of time.

Experiment	*Familiarisation time (s)*	*Age (months)*	*Mean total looking time (s)*	
			Same Room	*Different Room*
2a	20	12	8.83 (0.28)	9.07 (0.32)
	20	18	8.78 (0.21)	8.71 (0.36)
2b	10	12	8.00 (0.42)	7.85 (0.33)
	10	18	8.26 (0.35)	7.91 (0.32)

Table 3.3. Total looking times to the test stimuli in Experiment 2
The mean total looking time of groups of infants (n=12 per group) to the test stimuli in the *Same Room* and *Different Room* conditions. Standard errors are shown in parentheses. There were no significant effects of age or condition.

Novelty scores were then calculated for each infant. Preliminary analyses indicated that novelty scores were not significantly affected by either the picture set, the location of the test session, or the gender of the infant, so the data was collapsed across these variables.

Experiment	*Familiarisation time (s)*	*Age (months)*	Same Room	Different Room
2a	20	12	0.51 (0.02)	0.52 (0.03)
	20	18	0.51 (0.03)	0.52 (0.03)
2b	10	12	0.57 (0.03) *	0.42 (0.02) *
	10	18	0.57 (0.03) *	0.41 (0.02) *

Table 3.4. The effect of a change of room on recognition memory in 12- and 18-month-old infants.
Mean novelty scores by groups of infants (n=12 per group) in the Same Room and Different Room conditions of Experiment 2. Standard errors are shown in parentheses. An asterix indicates that preferences were significantly different ($p < 0.05$) to chance performance (0.5).

Table 3.4 shows the novelty scores shown by 12- and 18-month-old infants in the *Same Room* and *Different Room* conditions. A two-way ANOVA on Age (12- or 18-months) x Condition (*Same Room* or *Different Room*) revealed no significant effects (all $p > 0.05$). This reveals that there was no significant difference between the magnitudes of the novelty scores shown by infants of different ages, and no significant difference in performance in the *Same Room* and *Different Room* conditions.

Although an ANOVA reveals group differences, it does not indicate which groups of infants showed novelty scores that differed significantly from chance. Two-tailed one-sample t-tests were used to compare the percentage fixation to the novel stimulus to the chance level of responding (0.5). No group of infants showed a novelty score that differed significantly from chance responding (all $p > 0.05$).

With 20 seconds of familiarisation time, 12- and 18-month-old infants did not show evidence of recognition memory in either the *Same Room* or *Different Room* conditions. This result is surprising, given that 6- and 9-month-old infants recognised the same stimuli in an identical procedure in Experiment 1. It is possible that the results of Experiment 2 can be accounted for by over-familiarisation with the test stimuli. Twelve- and 18-month-old infants process information more quickly than younger infants, requiring less familiarisation time to produce equivalent novelty preferences (e.g., Robinson & Pascalis, 2004; Rose, 1983). Thus, in Experiment 2b infants were tested with 10 seconds of familiarisation.

3.3.2. Experiment 2b: 10 seconds of familiarisation

3.3.2.1. Participants

Twenty-four 12-month-old infants and twenty-four 18-month-old infants were recruited in the same way as for Experiment 1a. Testing was discontinued on 4 additional infants who were excessively fussy or cried during testing (one 12-month-old), failed to look at the test pictures for long enough (one 18-month-old), exhibited side bias during the test session (one 12-month-old), or due to experimenter error (one 18-month-old). Infants were all Caucasian and from families of moderate to high socio-economic status.

3.3.2.2. Apparatus, stimuli and procedure

These were identical to those used in Experiment 1a.

3.3.2.3. Results

Data were analysed in the same way as in Experiment 1. After screening total looking times, data from one 18-month-old infant were excluded for insufficient looking during the test session, and data from one 12-month-old infant were excluded for side bias. Looking times were then totalled across both test periods, to examine whether the groups showed any differences in overall looking time to the test stimuli (Table 3.3). An Age (12- or 18-months) x Condition (*Same Room* or *Different Room*) ANOVA on total looking times revealed no significant main effects, and no significant interaction. This confirmed that infants in all groups viewed the test stimuli for comparable lengths of time.

Novelty scores were then calculated for each infant. Preliminary analyses indicated that novelty scores were not significantly affected by either the picture set, the location of the test session, or the gender of the infant (all $p > 0.05$), so the data was collapsed across these variables.

Table 3.4 shows the novelty scores shown by 12- and 18-month-old infants in the *Same Room* and *Different Room* conditions. A two-way ANOVA on Age (12- or 18-months) by Condition (*Same Room* or *Different Room*) revealed a significant main effect of Condition ($F(1,47) = 38.636, p < 0.001$), reflecting the fact that novelty scores were larger in the *Same Room* condition than the *Different Room* condition. There were no other significant effects (all $p > 0.05$).

Two-tailed one-sample t-tests were used to compare the percentage fixation to the novel stimulus to the chance level of responding (0.5). In the *Same Room* condition, infants in both age groups showed significant preferences for the novel stimulus (12-months, $t(11) = 2.496, p = 0.03$; 18-months, $t(11) = 2.50$, p = 0.03). Intriguingly, 12- and 18-month-old infants in the *Different Room* condition showed a significant preference for the **familiar** stimulus (12-months: $t(11) = 4.193, p = 0.02$; 18-months: $t(11) = 3.934, p = 0.02$).

Both novelty and familiarity preferences represent discrimination between the stimuli on the basis of previous experience, an indication of recognition memory for the familiar stimulus. Thus, the present results indicate that 12- and 18-month-old infants recognised the familiar stimulus both in and out of the learning context in Experiment 2b. In contrast, 6- and 9-month-old infants in Experiment 1a did not show a significant preference for either stimulus. This indicates there may be age-related changes in the ability to recognise a stimulus out of the context of learning across the first two years of life. To examine this directly, the data from Experiments 1a and 2b were pooled and analysed together.

3.4. Overall Analyses and Discussion: Experiments 1a and 2b

With 10 seconds of familiarisation time, 12- and 18-month-old infants showed significant preferences for the novel stimulus in the *Same Room* condition, as did 6- and 9-month-old infants with 20 seconds of familiarisation time in Experiment 1a (Figure 3.2). To ascertain whether performance in the *Same Room* condition changed with age, novelty scores from the *Same Room* condition in Experiment 1a and 2b were combined and subjected to a one-way ANOVA by Age (6-, 9-, 12- or 18-months). This revealed no effect of Age (F (3,47) = 0.321, *n.s.*), indicating that novelty scores in the *Same Room* condition were equivalent across age-groups when 6- and 9-month-olds were given 20 seconds of familiarisation time, and 12- and 18-month-olds were given 10 seconds of familiarisation time.

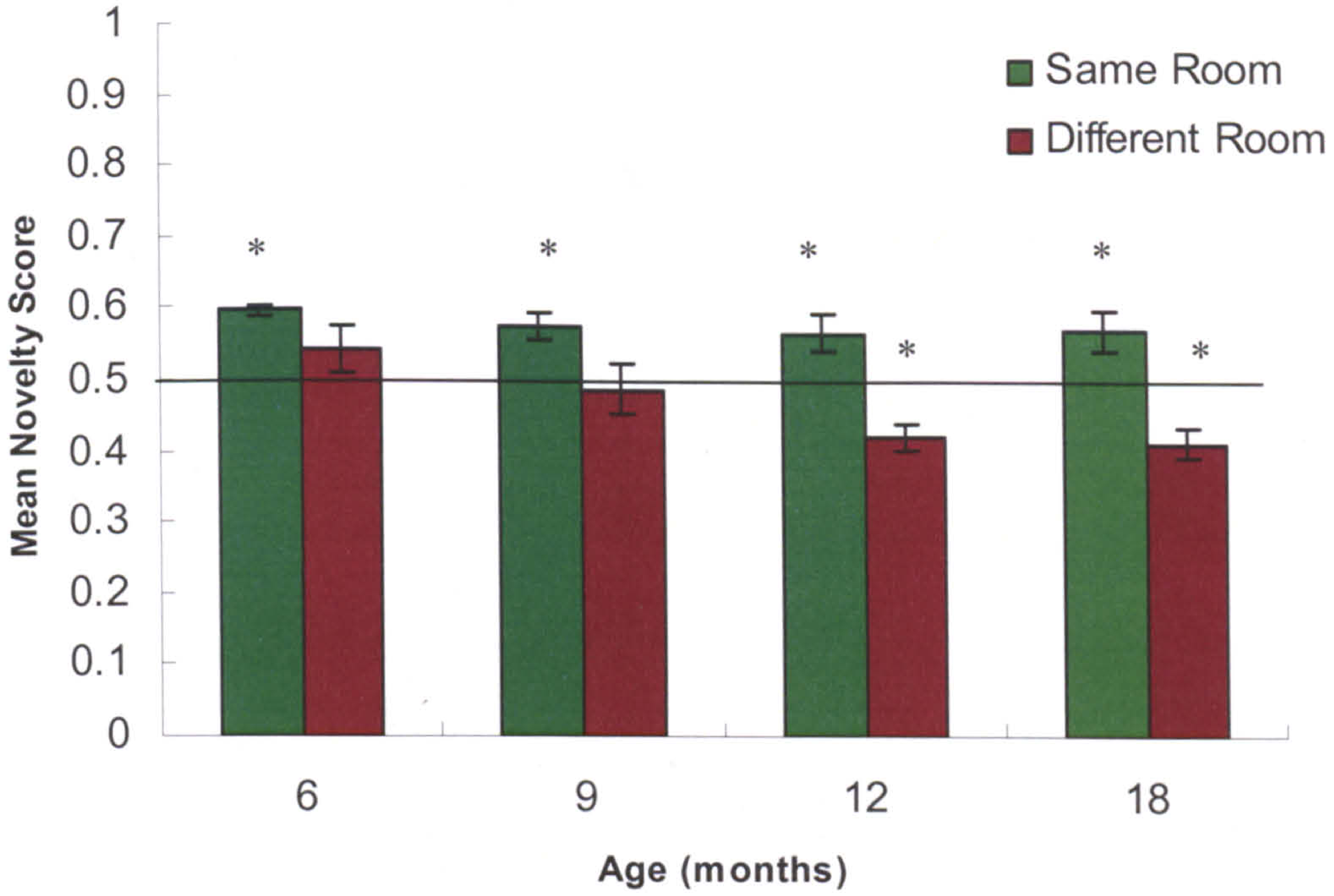

Figure 3.2. The effect of a change of room on recognition memory in 6- 18-month-old infants.

Mean novelty scores for independent groups of infants in Experiments 1a and 2b: An asterix indicates preferences were significantly different ($p < 0.05$) from chance (0.5). Error bars indicate +/- 1 SE.

Given comparability in performance in the *Same Room* condition, performance was examined in the *Different Room* condition. A one-way ANOVA on novelty scores by Age (6-, 9-, 12- or 18-months) revealed a main effect of Age (F (3,48) = 4.517, p = 0.008), indicating that older infants showed a stronger preference for the familiar stimulus than younger infants. Finally, performance in both conditions was subjected to a two-way ANOVA on Age (6-, 9-, 12- or 18-months) x Condition (*Same Room* or *Different Room*). This revealed a main effect of Age (F (3,95) = 3.963, p = 0.011) and a main effect of Condition (F (1, 95) = 38.570, $p < 0.001$). There was no significant interaction (F (3, 95) = 1.798, *n.s.*). Post-hoc tests confirmed that the main effect of Age resulted from a significant difference in novelty scores between the 6- and 12-month-old infants, and the 6- and 18-month-old infants ($p < 0.05$). This is unlikely to stem from the different familiarisation times used in Experiments 1a and 2b, because all age groups performed equivalently in the *Same Room* condition. Thus, the 12- and 18-month-old infants showed significantly stronger familiarity preferences than the 6-month-old infants, revealing age-related changes in the ability to recognise an unfamiliar stimulus out of the context of learning.

3.5. General Discussion

3.5.1. The influence of a change of global context on recognition memory in infancy

The first question addressed in the present study was whether a shift of global context influences recognition memory for 6- to 18-month-old infants. Although all four age groups exhibited recognition memory through a novelty preference when the familiarisation and test sessions were conducted in the same room, all four age groups showed a different pattern of behaviour when tested in a different room. This indicates that recognition memory for unfamiliar stimuli in the VPC was influenced by the congruency of the global context during the learning and test sessions for 6-, 9-, 12- and 18-month-old infants. By the logic of the encoding specificity principle (Tulving & Thompson, 1973), infants encoded details of the central stimulus and the room in which it was presented into memory, and both influenced memory retrieval.

The effect of a change of context on recognition memory in infancy in the present study adds to previous research demonstrating that cued recall and operant conditioning are influenced by shifts of global context in 6-, 9- and 12-month-old infants (Hartshorn *et al.*, 1997, 1998b; Hayne *et al.*, 2000), and further demonstrates that 18-month-old infants are also sensitive to contextual changes between learning and test sessions. The present study also extends the range of contexts which infants are known to represent. In previous studies, one of the contexts of testing has typically been the infant's home, with which they are presumably highly familiar (e.g., Bushnell *et al.*, 1984; Hayne *et al.*, 2000; Learmonth *et al.*, 2004). Not only do infants remember details of their home that allow them to distinguish it from an unfamiliar context (e.g., Hayne *et al.*, 2000), or one room in their home from another (Hartshorn *et al.*, 1997, 1998b), but the present study found that even 6-month-old infants encode sufficient details of a novel context to distinguish one laboratory room from another. Furthermore, infants only spent around a minute in each location, indicating that details of the novel context were rapidly assimilated in memory, along with details of the central stimulus. Global context is thus likely to exert pervasive influences on memory retrieval in infancy.

Unlike previous research that has employed infant-specific tasks (such as the mobile task), the VPC task can itself be used with adults, and is related to other recognition memory procedures that are traditionally used with adult populations (e.g., Manns *et al.*, 2000; McKee & Squire, 1993). In the present study, the context change and stimuli that produced a context-shift effect with 6- to 18-month-old infants were the same as those that have been previously used to obtain context-shift effects in some studies of recognition memory in adulthood (e.g., Dalton, 1993; Richmond *et al.*, 2004; Russo *et al.*, 1999; Smith & Vela, 1994). The comparability of procedures in which context-shift effects can be found with infants and adults makes it less parsimonious to conclude that contextual influence on memory retrieval occur through qualitatively different mechanisms in infants and adults. This further undermines the argument that there is a shift from 'context-free' to 'context-rich' memory in infancy (e.g., Bachevalier & Vargha-Khadem, 2005).

3.5.2. *Age-related changes in contextual influences on recognition memory*

The second question addressed in the present study was whether there are age-related changes in the influence of global context on recognition memory. Six- to 18-month-old infants showed the same magnitude of novelty preferences in the *Same Room* condition, indicating that there were no age-related changes in stimulus recognition in the present procedure when learning and testing occurred in the same context. However, in the *Different Room* condition 6- and 9-month-old infants showed null preferences, whereas 12- and 18-month-old infants showed significant familiarity preferences. When stimuli are unfamiliar to the infant, familiarity preferences are commonly obtained when familiarisation times are brief (Hunter *et al.*, 1982; Richards, 1997; Rose *et al.*, 1982; Slater, 1995), or when memory is tested after long retention intervals (Bahrick *et al.*, 1997; Bahrick & Pickens, 1995; Courage & Howe, 1998, 2001). Thus, familiarity preferences may result when there is only a partial match between external input and the internal stimulus representation (Bahrick & Pickens, 1995; Hunter & Ames, 1988). This account finds its roots in Solokov's model of looking behaviour in preferential looking paradigms, which states that infants will attend to a novel stimulus *once their representation of a familiar stimulus is complete* (Solokov, 1963). This explanation can account for the present results, if it is assumed that infants integrate details of stimuli and their contexts in their memory traces. When encoding and retrieval occur in different global contexts, there is only a partial match between the internal representation and the external input. The 12- and 18-month-old infants may thus have oriented to the familiar stimulus in order to update their internal representation of that stimulus, perhaps including details of the new context in which it was encountered.

Twelve- and 18-month-old infants clearly recognised the test stimulus when it was presented out of the context of learning. In contrast, 6- and 9-month-old infants did not show any evidence of recognition memory when learning and retrieval occurred in different rooms. This may reflect the fact that in the absence of global contextual cues, the test stimulus itself was not sufficient to drive a preference. The age-related changes in the influence of a shift of global context on recognition memory between 6- and 12-months seen in the present study complement similar developmental trajectories in the deferred imitation (Hayne *et al.*, 2000) and operant conditioning tasks (Hartshorn *et al.*, 1998b). Clearly, there are broad changes in the ability to retrieve memory in different global contexts in the second half of the first year of life.

The present results narrow the range of potential explanations for this developmental process. In previous studies, infants have either been tested in highly familiar environments (e.g., Hartshorn *et al.*, 1998b), or over relatively long retention intervals (e.g., Hayne *et al.,* 2000). In the present study, memory was tested in a novel context over a short retention interval, reducing the likelihood that age-related changes in the familiarity of the testing context, or the rate at which information is forgotten, can fully account for the age-related changes in context-shift effects observed. A number of studies have found that performance in the VPC is dependent on the integrity of the hippocampal formation when memory is measured over a short delay, as in the present study (reviewed in Section 2.2.3). Furthermore, research with animals shows that incidentally-presented environmental contextual information, like the room in which participants are tested, is likely to exert an influence on memory through hippocampally-based processes (e.g., Mumby *et al.*, 2002; reviewed in Section 1.5.1). The present study thus provides further evidence that age-related changes in context-shift effects in infancy may reflect age-related changes in hippocampal functioning (e.g., de Haan, Mishkin, Baldeweg, & Wargha-Khardem, 2006; Hayne, 2004; Richmond & Nelson, 2007; Robinson & Pascalis, 2004).

3.5.3. The influence of stimulus novelty

Six- and 9-month-old infants had not necessarily completely forgotten the familiarisation stimulus when they saw it in a different room. This is because a null preference does not necessarily indicate complete forgetting (Houston-Price & Nakai, 2004; Hunter & Ames, 1988; Pascalis & de Haan, 2001; see Section 2.2.7 for discussion). Thus, it cannot be concluded that 6- and 9-month-old infants are *unable* to recognise people when they meet them 'out-of-context'. Furthermore, the use of novel stimuli may make recognition in an alternate context particularly difficult for infants. As adults rely less on global context to cue retrieval when stimuli are familiar (e.g., Dalton, 1993; Russo *et al.*, 1999), 6- and 9-month-old infants may be less constrained by contextual cues when recognising objects or people that they have encountered many times before. Indeed, it is clear that infants recognise their mother in a variety of contexts from shortly after birth (e.g., Bushnell, 2001; Bushnell, Sai & Mullin, 1989; Field, Cohen, Garcia & Greenberg, 1984). Encountering a stimulus in many different contexts may enable the development of an 'independent' representation of that stimulus, which can then be encoded and remembered with little influence from contextual variation (e.g., O'Reilly, 2001; Pan, 1926; Rothkopf, Fisher & Billington, 1982). Indeed, this may be why variability training is so effective in the mobile task for 3- and 6-month-old infants (Amabile & Rovee-Collier, 1991; Rovee-Collier & DuFault, 1991). Manipulating the duration and nature of exposure to a stimulus with infants of different ages may illuminate the processes by which stable, context-free representations of individuals or objects develop.

3.5.4. What details of the global context were important?

One limitation of exploring a change of global context is the difficulty in identifying the precise contextual elements that were important in memory retrieval. However, it is important to consider the contextual features that could potentially have driven the observed effects. Notably, the lights were turned off during the VPC procedure in both testing rooms. Although some details of the rooms would have been visible by the light of the stimulus on the screen, these would have been very poorly defined. Furthermore, infants viewed the test stimuli for the majority of the time they were presented (with mean total looking times of approximately 8 seconds out of the 10 seconds available), rather than looking around the room. Non-visual features of the room (such as its temperature) may have played a role. Indeed, previous research with a VPC task has demonstrated that auditory or olfactory aspects of the context can cross-modally influence recognition memory for visual stimuli (Fernandez & Bahrick, 1994; Pescara-Kovach *et al.*, 2000).

Alternatively, details the infant noticed prior to the presentation of the test stimuli may be important. In contextual-fear conditioning paradigms conducted with rats, a period of familiarisation in a context is required before rats learn to associate a context with a shock (Fanselow, 1990). This familiarisation time may enable rats to build a conjunctive representation of the context, which can then enter into an association with the shock stimulus (Fanselow, 1990; Rudy & O'Reilly, 1999). Indeed, if experiences leading up to an immediate shock (such as travelling in a particular carry-box) have been previously associated with a particular context, the fear response is conditioned to the expected context rather than the one in which the rat is currently situated (Rudy & O'Reilly, 2001, Rudy, Barrientos, & O'Reilly, 2002). In the present study, the representation infants formed of the testing room as they were brought in by their parents may have been linked to the representation of the test stimulus, even though the two were not concurrently visible. This remains a question for further research.

3.5.5. Global context in operant conditioning, deferred imitation and recognition memory paradigms

Details of the global context of learning are encoded in memory and influence retrieval under some circumstances in operant conditioning, deferred imitation and the VPC. However, it appears that for 9- and 12-month-old infants, memory is influenced by a global context change over different retention intervals in different paradigms (Hartshorn *et al.*, 1998b; Hayne *et al.*, 2000; Herbert *et al.*, 2007). For example, in the train task, 9- and 12-month-old infants only require a congruent global context for encoding and retrieval when sessions are separated by a 42- or 56-day delay respectively, and a global context change has no influence over a 24-hour retention interval (Hartshorn *et al.*, 1998b). In contrast, in the present study recognition memory in the VPC task was affected by a global context-shift over a delay of just 1 minute. Possibly, memory retrieval is only affected by a global contextual shift when 9- and 12-month-old infants are tested over very short or very long retention intervals. Indeed, research with animals and human adults has revealed U-shaped curves in contextual influences on memory retrieval over time (Bertsch & Sanders, 2005; Land & Riccio, 1998; Borovsky & Rovee-Collier, 1990). However, when 12-month-old infants are tested in a deferred imitation task over a 3-minute delay, memory retrieval is not influenced by a move from a polka-dot tent to an ordinary University room (Klein & Meltzoff, 1999), indicating that infant memory is not always influenced by an contextual change over short retention intervals.

Alternatively, the VPC paradigm may be more sensitive to context-shift effects than other paradigms. Indeed, a change of background precludes memory retrieval for 12-month-old infants in the VPC when memory is tested immediately, suggesting that memory may be particularly vulnerable to context changes in this task (Robinson & Pascalis, 2004). Many procedural aspects of the VPC could account for any heightened context-sensitivity. For example, the familiarisation sessions in the VPC are typically shorter than those employed in deferred imitation or operant conditioning tasks (e.g., Pascalis & Robinson, 2004; Hayne *et al.*, 2000; Hartshorn *et al.*, 1998b), and longer learning sessions may reduce the magnitude of context-shift effects in infancy (Millin & Riccio, 2004). Alternatively, the lack of salient local cues remaining constant between learning and retrieval in the present study may have rendered retrieval particularly dependent on global contextual details.

The type of memory required in a particular task may also be important in determining the contextual sensitivity of performance. For example, spatial memory may be particularly affected by a context change. When 14-month-old infants observe an experimenter hide a toy in a particular cupboard in an experimental room, they will search for the toy in the cupboard 24-hours later. However, when features of the room, the shape of the interior space, and the path taken to reach the room are different during the test session, 14-month-old infants no longer search for the toy, even through the same cupboard is present (Moore & Meltzoff, 2004). This could either be attributed to a failure of memory retrieval in the altered context, or to the fact that the infants do not expect the toy to be located in the novel room. In either case, it appears that the expression of location memory in 14-month-old infants is more constrained by contextual details than memory for actions in the deferred imitation task for 12-18-month-old infants (Hayne *et al.*, 2000). It is plausible that the types of memory required in operant conditioning, deferred imitation and VPC tasks are also differentially sensitive to a context change.

3.5.5. Global and local context in infant memory

The context of learning clearly plays an important role in memory retrieval for 6- to 18-month-old infants, enabling infants to recognise objects and people more easily when they are encountered in the context in which they are typically located. Between 6- and 12-months, infants show evidence of increasing generalisation across changes in the global context of learning, becoming more able to recognise people and objects in different locations through the first two years of life. Other contextual changes are equally important to explore. For example, objects may be placed on different surfaces, or backgrounds. Different people may be present on the occasions when infants are playing with the same object. What influence do these sorts of changes have on memory in infancy? For adults, it seems that discrete sources of information such as the background upon which stimuli are presented (Murnane & Phelps, 1999), or the experimenter running the learning and test sessions (Smith & Vela, 2001), can also provide important cues to memory retrieval. The importance of people and backgrounds in memory retrieval in infancy is explored in the next Chapter.

Chapter 4: The effect of a change of local context on memory in 6- and 9-month-old infants

4.1. Introduction

The aim of the experiments presented in this Chapter was to explore the influence of social and local physical context on memory retrieval in infancy.

4.1.1. Local physical context

In research with infants, local physical context has been defined differently in different paradigms. In the VPC, local physical context has been defined in a similar way to studies with adults, by the background upon which stimuli are presented. When tested immediately, 6- and 12-month-old infants do not show evidence of memory in the VPC task when stimuli are presented on one coloured background during familiarisation, and a different coloured background at test (Haaf *et al.*, 1996; Robinson & Pascalis, 2004). However, recognition memory in 18- and 24-month-old infants is not affected by this manipulation (Robinson & Pascalis, 2004). In the mobile task, local physical context has typically been defined as the distinctive colour and pattern of the lining of the crib in which infants are tested (e.g., Borovsky & Rovee-Collier, 1990; Shields & Rovee-Collier, 1992). A context change is usually effected by switching the colour and/or pattern of the liner (such as green squares on a yellow liner to red stripes on a blue liner). Memory in the mobile task is precluded by such a change for 6-month-old infants tested over a 24-hour delay (e.g., Borovsky & Rovee-Collier, 1990; Shields & Rovee-Collier, 1992). Older infants have not been tested with a change of local physical context in this task.

Only one study has explored the effect of a change of local physical context with a deferred imitation task (Learmonth *et al.*, 2004). Learmonth and colleagues used similar liners to those typically used in the mobile study (this time, blue with pink circles and green with yellow stripes), but used them to form a mat upon which the infant and experimenter were seated. Using different mats for the learning and test sessions had no influence on retrieval for 6-, 9- or 12-month-old infants when memory was tested over a

24-hour delay. Thus, a change of mat has no effect on cued recall over a 24-hour delay when global environmental cues are consistent.

Why might memory retrieval in the deferred imitation paradigm be less affected by a change of local physical context than memory retrieval in the mobile or VPC tasks? The way in which local physical context has been defined in different infant memory tasks may hold the solution. A mat located beneath the infant may be less salient than the crib liner surrounding the infant in the mobile task, or the distinctive background of a picture stimulus in the VPC task, because the mat is not in the infant's line of sight whilst they are viewing the test stimulus. Exploring the effect of changing a distinctive background in a deferred imitation task might reveal whether the relative salience of different local contextual cues is sufficient to account for the lack of sensitivity to changes of local physical cues previously seen in the deferred imitation task. Alternatively, the experimenter may be more salient in the deferred imitation task than in the other two paradigms (Learmonth *et al.*, 2005), overshadowing the role of other local physical cues. The importance of people in learning and memory in infancy is considered in the next section.

4.1.2. Social context

Social factors during learning have a large impact on memory in infancy. For example, in a deferred imitation task, 18-month-old infants will imitate the 'failed attempts' of an adult experimenter, but will not produce the same behaviour when they have observed a mechanical device perform the same 'failed attempt' (Meltzoff, 1995). At this age, infants will also modify their imitative behaviour based on the behaviour of the experimenter, reproducing twice as many of an experimenter's actions that were marked by a verbal commentary of 'there!', than were marked by a commentary of 'whoops!' (Carpenter, Nagell & Tomasello, 1998). Social information during learning also has an influence on object recognition memory. Cleveland and Striano (2007) found that 9-month-old, but not 4-month-old infants, showed evidence of stronger recognition memory for an object that had been involved in a joint attention interaction with the experimenter (where the experimenter alternated gaze between object and infant), than for an object to which the experimenter had simply attended (alternating gaze between the object and the ceiling). Social factors during learning thus influence both recall and recognition memory in infancy. However, these studies do not reveal the influence of social context on memory retrieval.

The importance of social context for memory retrieval can be assessed by having different experimenters run the demonstration and test conditions. However, it is first important to consider the effect stranger wariness may have on results. 'Wariness' has been defined as "the tendency to inhibit approach or to avoid novel objects and persons" (Sroufe, 1977, p.732), and this may prevent infants from expressing their memories in the presence of a stranger. In a memory task, this question can be partially addressed by measuring the latency to interact with the stimulus. If latencies are longer in the presence of a novel experimenter, wariness may be playing a role. In general, the degree of stranger wariness observed increases between 6- and 12-months (Emde, Gaensbauer & Harmon, 1976; Waters, Matas, & Sroue, 1975). However, wariness is unlikely when the stranger approached the infant with a toy (Bretherton & Ainsworth, 1974; Rheingold & Eckerman, 1973) or in order to play with the infant (Rafman, 1974). Indeed, infants show virtually no wariness when their mother interacts with the experimenter, the infant is pre-exposed to the experimenter, and the experimenter approaches with a toy (Rheingold & Eckerman, 1973). These conditions are exactly those used in typical infant memory procedures, and thus it is unlikely that stranger wariness will play a large role in any experimenter change effect, provided the experimenter has been encountered prior to the test session.

The deferred imitation paradigm has been used to explore the role of the experimenter in infant memory (Hanna & Meltzoff, 1993; Klein & Meltzoff, 1999; Learmonth *et al.*, 2005). This paradigm is particularly suitable because the experimenter plays a major role, presenting the toy to the infant during both the encoding and retrieval sessions. Broadly, social context changes do not affect deferred imitation in the second year of life (Hanna & Meltzoff, 1993; Klein & Meltzoff, 1999). For example, Klein and Meltzoff (1999) showed 12-month-old infants a sequence of target actions in their home (Klein & Meltzoff, 1999). After a 1-week delay, a second experimenter tested their recall of the target actions in the laboratory. The infants showed significant evidence of deferred imitation despite the change in both physical and social context. Thus, despite the central role the experimenter plays in this task, infants as young as 12- months are able to retrieve their memory for the deferred imitation task in the absence of the experimenter who originally demonstrated the target actions.

As younger infants appear to be more constrained by contextual congruency than older infants (e.g., Hayne *et al.*, 2000; Chapter 3), memory in younger infants may be more susceptible to the presence of different experimenters at encoding and retrieval. In the only study to examine the influence of a change of experimenter on deferred imitation in infants younger than 12-months, Learmonth *et al.* (2005) tested 6- , 9- and 12-month-old infants in their home. No age group showed evidence of memory retrieval if the second experimenter was completely novel to the infant, which the authors interpret as an effect of 'social neophobia'. However, 9- and 12-month-old infants showed evidence of memory retrieval with an alternate experimenter if they had received 5-minutes of familiarisation with her two days prior to the test session. For 9- and 12-month-old infants, the experimenter does not appear to provide crucial cues for memory retrieval, but a completely novel experimenter disrupts performance in some circumstances. Six-month-old infants retrieved their memories for the target actions across a change in experimenter when both experimenters were present during the demonstration session. This indicates that 6-month-old infants do not require all aspects of social context to be maintained between encoding and retrieval. However, it is unclear whether 6-month-olds, like 9-month-olds, would show evidence of deferred imitation if no aspects of social context were maintained between encoding and retrieval, because this condition was not included in Learmonth and colleagues' study. Thus, it remains unclear whether there are age-related changes in the ability to retrieve memory across a change of social context in infancy.

4.1.3. The present study

The present study explored the role of social and local physical context in memory retrieval with 6- and 9-month-old infants. There is clear evidence that by 12-months, infants are able to retrieve memory in the deferred imitation task in a different global environment and in the absence of the experimenter who initially demonstrated the target actions (Klein & Meltzoff, 1999). In contrast, the role played by social context and local physical context for 6- and 9-month-old infants is less clear. However, it is plausible that there are important developmental changes across this age range. Previous research indicates a development between 6- and 9-months in the ability to transfer memory from one stimulus to another (Learmonth *et al.*, 2004), or from one room in their home to another over a 24-hour delay (Hartshorn *et al.*, 1998b). This implies that there may be important age-related changes in the ability to retrieve memories in alternate contexts between the ages of 6- and 9-months. In order to examine age-related change in contextual influences on memory retrieval whilst minimizing the potentially confounding influence of age-related changes in forgetting function, infants were tested over a 10-minute delay. A delay of 10 minutes is considered to be a measure of long-term memory in deferred imitation tasks (Abravanel, 1985, 1991; Barnat *et al.*, 1996; Bauer, Van Abbemea & de Haan, 1999; Heimann & Meltzoff, 1996).

4.2. Experiment 3: The effect of a change of social and physical context on memory retrieval in a deferred imitation task

4.2.1. Experiment 3a: A change of background or a change of experimenter

Experiment 3a explored the role of local physical context, and the role of the experimenter, in memory retrieval in a deferred imitation task with 6- and 9-month-old infants. The particular deferred imitation task chosen was the 'puppet task', a task that has been used many times with 6-, 9- and 12-month-old infants (e.g., Barr *et al.*, 1996; Hayne *et al.*, 2000; Learmonth *et al.*, 2004, 2005). The local physical context used was brightly coloured and patterned cloth, which provided a background to the deferred imitation task (Figure 4.1). This was chosen to be comparable to the changes typically made in the mobile task (a distinctive crib liner surrounding the infant; e.g., Borovsky & Rovee-Collier, 1990; Shields & Rovee-Collier, 1992), and the VPC task (the background of the stimulus; Coldren & Haaf, 1999; Haaf *et al.*, 1996; Robinson & Pascalis, 2004).

Figure 4.1. The room in which the deferred imitation paradigm was carried out in Experiments 3, 4 and 5.
The checked material behind the experimenter was defined as the local physical context of the testing procedure. The experimenter is shown on the left; the infant is seated on her mother's knee.

The importance of this surround as a retrieval cue was assessed by testing a group of infants with a surround of a different colour and pattern to that used during the demonstration session. To directly assess the role of the experimenter in memory retrieval in the deferred imitation task, a group of infants were tested by a different experimenter to the experimenter that ran the demonstration session. Importantly, this experimenter was not present during the demonstration session, but the infant was familiarised with both experimenters before the deferred imitation procedure began (c.f. Learmonth *et al.*, 2005).

4.2.1.1. Participants

Forty-eight 6-month-old infants (30 male) and 48 nine-month-old infants (30 male) were recruited from a database of infants born at the Jessop's Maternity Ward of the Hallamshire Hospital, Sheffield. Each group contained equal numbers of male and female infants. Infants were tested within ten days of their 6- or 9-month birthday respectively. No infant was born more than 3 weeks premature, and no infant had experienced birth complications. Testing was discontinued on 12 additional infants who were excessively fussy or cried during testing (n = 11), or failed to respond during the warm-up phase described below (n = 1). This is commensurate with attrition rates in previous studies with this task (e.g., Barr & Hayne, 1996). All infants were Caucasian. This study, and all subsequent studies, were approved by the Department of Psychology ethical committee.

4.2.1.2. Apparatus

The stimuli were four hand puppets: a rabbit and a mouse (30 cm in height), both made in a pink and a grey version. Identical puppets have been used previously in studies of deferred imitation with this age group (e.g., Hayne *et al.*, 2000). The colour and form of the puppet used was counterbalanced across age, gender, and experimental condition. A removable felt mitten (8 cm x 9 cm) was placed over the right hand of each puppet and matched the colour of the puppet. A large jingle bell was secured to the inside of the mitten in demonstration conditions or the back of the puppet in the control conditions. The bell was removed during the test session in all conditions to ensure that memory performance was not prompted by the sound of the bell.

To create a distinctive visual surround, one of two brightly coloured and patterned sheets of material (3m x 1m) was placed immediately behind the experimenter (see Figure 4.1). One sheet of material was red with blue squares (15 cm x 15 cm); the other was yellow with green circles (15 cm x 15 cm). The material was draped over a wooden frame that formed three sides of a square (1m x 1 m x 1 m) around the experimenter. The colour of the background used was counterbalanced across age, gender, and experimental condition.

Four different female experimenters were involved in this study. EJ tested infants in all four conditions. JH, LC and JD were involved in testing infants in the *No Change*, *Baseline*, and *Experimenter Change* (*fDL*) conditions.

4.2.1.3. General Procedure

Infants were randomly assigned to one of three demonstration conditions (*No Change, Background Change, and Experimenter Change with familiarisation in a Different Location* (*Experimenter Change fDL*)) or to the *Baseline* condition. There were 6 male and 6 female infants of each age in each condition. All infants participated in a demonstration session and a testing session which was separated by approximately 10 minutes. Infants were tested in the laboratory at a time of day that was defined by the caregiver as an alert/play period. A female experimenter interacted with the caregiver and the infant in the Reception Room for approximately 5 minutes until the infant appeared comfortable with the experimenter. During this time informed consent was obtained from the caregiver. In the Experimenter *Change fDL* condition, two female experimenters were present throughout this period and both interacted with the infant and caregiver.

During the demonstration and test sessions, the infant sat on their caregiver's lap on a chair in the Experimental Room. The experimenter knelt in front of the infant and caregiver. Importantly, the demonstration and test sessions followed those used in previous studies with this task in all major respects (e.g., Barr *et al.*, 1996; Hayne *et al.*, 2000; Learmonth *et al.*, 2004, 2005). A warm-up phase was first conducted to ensure that infants were willing to interact with objects offered to them by the experimenter, and that they were able to engage in visually-guided reaching. The experimenter offered the infant a plastic toy, and interacted with the infant until he or she either took the toy, or three minutes had elapsed.

4.2.1.3.1. Demonstration session

Immediately following the warm-up phase, the experimenter placed a puppet on her right hand, out of the infant's sight. The puppet was then bought up to the infant's eye level at a distance of approximately 30 cm, just out of reach of the infant. If the infant failed to visually orient to the puppet, the experimenter attempted to draw the infant's attention to the puppet by saying 'Look', and the baby's name. Once the infant was attending to the puppet, the experimenter demonstrated a sequence of three target actions. First, she removed the mitten from the puppet's right hand. Second, she shook the mitten three times, ringing the bell inside it. Third, she replaced the mitten on the puppet's right hand. This sequence of actions lasted approximately 15 seconds and was repeated six times in total. The entire demonstration session lasted approximately two minutes, during which time the infant was unable to touch the puppet or perform the target actions.

During the demonstration, the experimenter used only general verbal comments such as 'look at this' to elicit and maintain the infant's attention to the puppet. The experimenter and the caregiver did not label the puppet or any of the target actions. At the end of the demonstration the puppet was removed from the infant's sight. The infant, caregiver, and experimenter then returned to the Reception Room where they continued to interact together for the 10-minute delay interval. In the *Experimenter ChangefDL* condition both Experimenters interacted with the infant and caregiver during the delay.

4.2.1.3.2. Baseline Demonstration

The baseline procedure used in the present study was that used in previous studies with the puppet task (e.g., Barr *et al.*, 1996; Hayne *et al.*, 2000; Learmonth *et al.*, 2004, 2005). Infants in the *Baseline* condition received the same amount of exposure to the puppet, the ringing of the bell, and the experimenter as infants in the Demonstration conditions, but the target actions were never demonstrated. The experimenter held the puppet just out of reach of the infant, and shook the puppet three times, causing the bell attached to the back of the puppet to ring. The sequence of actions lasted approximately 15 seconds and was repeated six times in total. The entire baseline demonstration took approximately two minutes. All other details of the baseline demonstration were identical to those experienced by infants in all of the demonstration groups.

4.2.1.3.3. Test session

At the end of the 10-minute retention interval, the infant was returned to the experimental room. Once the infant was reseated on their caregiver's lap, the experimenter removed the demonstration puppet from the bag and placed it over her right hand. The puppet was placed approximately 20cm in front of the infant, within comfortable reach. The infant was then allowed to freely explore the puppet. During the test session, the experimenter and caregiver did not prompt the infant's behaviour.

For infants in the *No Change* and *Baseline* conditions, the demonstration and test sessions were conducted by the same experimenter, and the same coloured background was used. For infants in the *Background Change* condition, the bright background material was changed between the demonstration and test sessions. For example, infants who observed the demonstration with the blue and red background were tested with the yellow and green background. For infants in the *Experimenter ChangefDL* condition, the background remained constant between demonstration and test, but a second female experimenter held the puppet during the test phase. The original experimenter, who had demonstrated the target actions, was absent from the experimental room.

4.2.1.4. Results and Discussion

The scoring and analysis of the data followed previous research in all major respects (e.g., Barr *et al.,* 1996; Hayne *et al.*, 2000; Learmonth *et al.*, 2004, 2005). The entire test session was videotaped for subsequent analysis. One observer scored the presence or absence of three target behaviours during the test: (a) remove the mitten, (b) shake the mitten, (c) replace, or attempt to replace, the mitten[6]. Infants were allowed 90 seconds from the time they first touched the stimulus to produce the target actions. A second independent observer scored a randomly chosen 50% of the sessions. A Pearson product-moment correlation yielded an inter-observer reliability coefficient of 0.98. An imitation score was calculated for each infant by summing the number of target behaviours he or she produced during the test session (range 0 to 3). Infants were only given credit for the first time they produced each target action. Preliminary analyses confirmed that scores were not significantly influenced by the gender of the infant, the particular stimulus used, the particular experimenter who ran the demonstration or test session, or the particular distinctive background used during the demonstration or test sessions, and so further analyses were collapsed across these variables (all $p>0.05$).

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[6] An infant was judged as having replaced the mitten when they placed the mitten in the correct orientation on or next to the correct hand of the puppet. This was to ensure that infants were not prevented from scoring a total of three points through a lack of the co-ordination necessary to fully replace the mitten on the puppet's hand.

Observers coded the latency to touch the puppet from the time of its presentation, and the latency of any target actions that were produced. Latency data were examined to determine whether any group of infants was reticent to touch the puppet. Examination of the data revealed one outlier, which was removed from subsequent analyses (a 6-month-old infant in the *Experimenter Change fDL* group, who took 178 seconds to interact with the puppet). An ANOVA on the mean latencies of each group of infants (Figure 4.2) by Age (6- or 9-months) and Condition (*Baseline, No Change, Experimenter Change fDL,* or *Background Change*) revealed no main effects and no significant interaction ($p > 0.05$). However, the main effect of Condition approached significance ($F(3,72) = 2.61$, $p = 0.06$), and inspection of Figure 4.2 reveals that this was probably due to infants in the *Baseline* condition tending to interact with the puppet more quickly than infants in the other conditions. Thus, changes in environmental or social context did not result in infants being any slower to interact with the puppet at test.

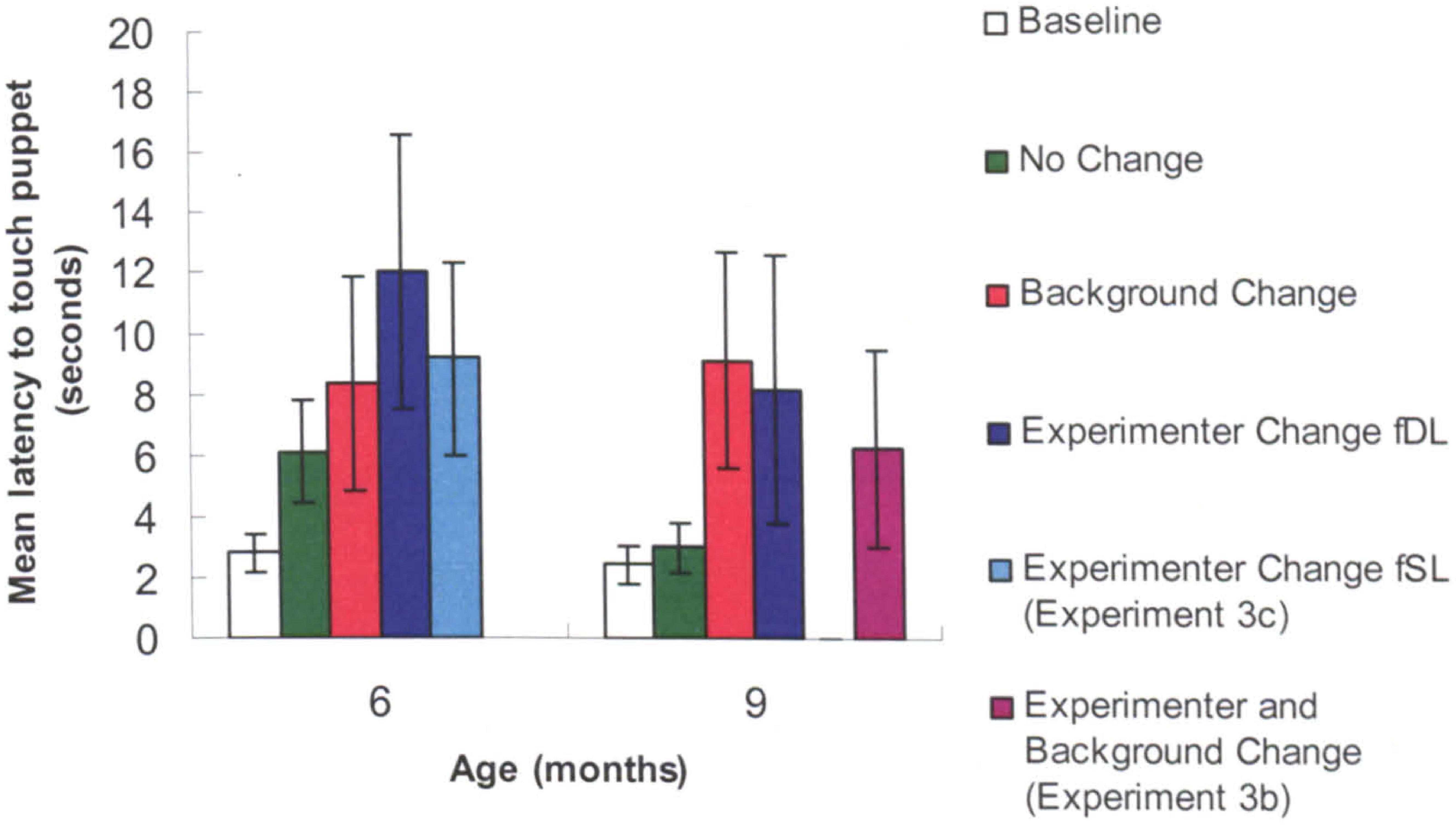

Figure 4.2. Latency to touch the test stimulus in Experiment 3.
The mean latency of each group of infants (n=12 in each group) to touch the puppet from the time of presentation. Error bars indicate +/- 1 Standard Error. There were no significant effects of age or condition.

Tables 4.1 and 4.2 show the range of scores produced by each group of infants. This data reveals that spontaneous production of the target actions in the *Baseline* condition was rare, confirming the novelty of the demonstrated target actions.

Number of target actions	*0*	*1*	*2*	*3*
No Change	2	5	5	0
Background Change	5	4	3	0
Experimenter Change (fDL)	10	0	2	0
Experimenter Change (fSL) (Experiment 3c)	3	4	5	0
Baseline	11	1	0	0

Table 4.1. The number of 6-month-old infants producing 0, 1, 2 or 3 target actions in each condition in Experiment 3.
A score of 1 indicates that the infant removed the mitten, a score of 2 indicates they removed the mitten and either shook or replaced/attempted to replace the mitten, and a score of 3 indicates they performed all three actions.

Number of target actions	*0*	*1*	*2*	*3*
No Change	5	2	4	1
Background Change	4	4	1	3
Experimenter Change (fDL)	5	2	4	1
Experimenter and Background Change (Experiment 3b)	4	3	5	0
Baseline	11	0	1	0

Table 4.2. The number of 9-month-old infants producing 0, 1, 2 or 3 target actions in each condition in Experiment 3.
A score of 1 indicates that the infant removed the mitten, a score of 2 indicates they removed the mitten and either shook or replaced/attempted to replace the mitten, and a score of 3 indicates they performed all three actions.

To analyse whether changes in physical or social context influenced memory retrieval, a two-part analysis strategy was employed (e.g., Barr *et al*., 1996; Hayne *et al*., 2000; Learmonth *et al*., 2004, 2005) This strategy uses the mean number of actions produced by each group of infants as the dependent variable (Figure 4.3).

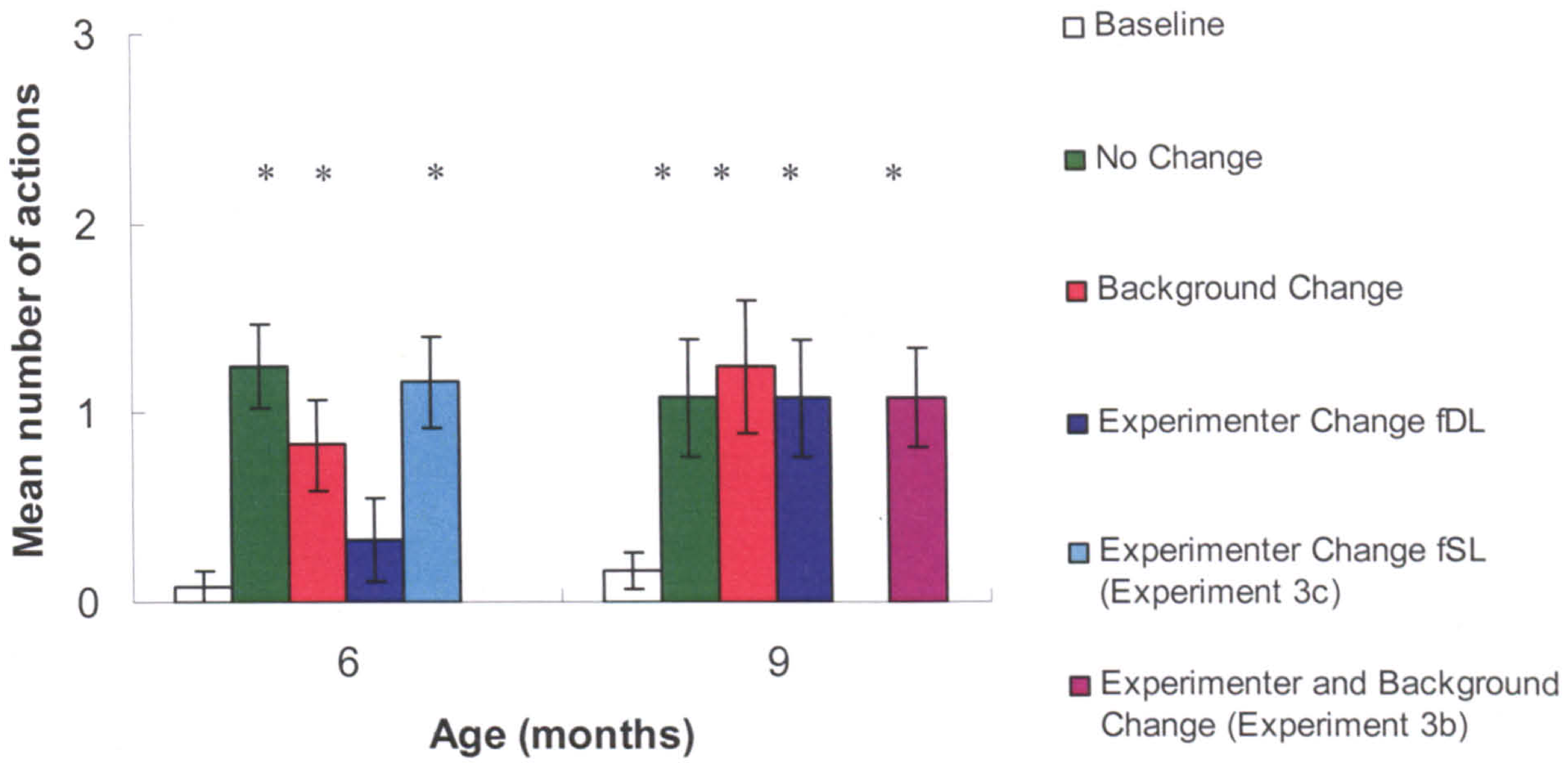

Figure 4.3. Effect of an experimenter change or background change on cued recall in 6- and 9-month-old infants.
The mean number of actions (+/- 1 SE) produced by groups of infants in Experiment 3. An asterix indicates that the mean imitation score of a group is significantly greater than the mean of the age-matched *Baseline* group ($p < 0.05$).

The first part of the strategy was to assess whether there were any group differences in imitation score between infants in the Demonstration conditions. To do this, the data were subjected to a two-way Analysis of Variance (ANOVA) with age (6- or 9-months) and condition (*No Change*, *Background Change*, *Experimenter Change fDL*) as the two variables. There were no significant main effects, and no significant interactions, indicating that there were no significant variations in performance between the two age groups, or between the various demonstration conditions.

This analysis does not indicate whether a particular group showed retention of the target actions. Retention can only be inferred if the mean number of target actions produced by a demonstration group is significantly greater than the mean number of target actions spontaneously produced by their age-matched control group. Thus, the second part of the analysis strategy assesses whether any of the test groups met this criterion. To do this, the mean number of target actions produced by each demonstration group was compared to the *Baseline* group with independent-samples t-tests.

For the 6-month-olds, infants in the *No Change* condition (t (14) = 5.01, p <0.001) and the *Background Change* condition (t (14) = 2.94, p = 0.01) exhibited significant levels of deferred imitation. Thus, the change of background had no detectable effect on memory retrieval in the deferred imitation test. However, infants in the *Experimenter Change fDL* condition did not show significant levels of deferred imitation (t (14) = 1.37, *n.s.*). In order to test whether the change of Experimenter had a significant effect on retention, the scores of 6-month-old infants in the *No Change* and *Experimenter Change fDL* conditions were compared with a two-tailed independent samples t-test. This revealed that the change of experimenter significantly reduced imitation scores for 6-month-old infants (t (22) = 2.93, p = 0.01).

For 9-month-old infants, infants in all three demonstration conditions showed significant levels of deferred imitation (*No Change* condition: t (17) = 2.59, p = 0.019; *Background Change* condition: t (16) = 2.79, p = 0.013; *Experimenter Change fDL* condition: t (17) = 2.59, p = 0.019). Neither a change of background, nor a change of experimenter affected 9-month-old infants' memory retrieval in a deferred imitation task.

To explore whether there were age-related changes in the influence of a change of social context on memory retrieval in the deferred imitation task, the mean numbers of actions produced by 6- and 9-month-old infants in the *Experimenter Change fDL* condition were compared with a further independent samples t-test. Although not significant, there was a trend for 9-month-olds to produce more actions than 6-month-olds in the *Experimenter Change fDL* condition (t (22) = 1.95, p = 0.06). Thus, there is an indication that the influence of social context on memory retrieval may decline between 6- and 9-months, but this conclusion is presently tentative.

Before these results can be interpreted further, it is necessary to further explore two aspects of the data. First, did 9-month-old infants succeed in the *Experimenter Change fDL* condition because they relied on the distinctive visual surround to provide an alternate source of retrieval cues, or because they were able to retrieve memory for the puppet task without any local cues? This question was addressed in Experiment 3b. Second, why did 6-month-old infants fail to imitate the target actions in the *Experimenter Change fDL* group? This issue was further probed in Experiment 3c.

4.2.2. Experiment 3b: A change of both background and experimenter

To examine whether 9-month-old infants used the distinctive background as an alternate source of retrieval cues in the *Experimenter Change fDL* condition, an additional group of infants were tested in an *Experimenter and Background Change* condition. If 9-month-old infants were using the background as an alternate retrieval cue when the demonstrating experimenter was absent in the test session, they should fail to show evidence of memory retrieval when both the experimenter and background were switched between the learning and test sessions.

4.2.2.1. Participants

Twelve 9-month-old (6 female and 6 male) infants were recruited in the same way as for Experiment 3a. Testing was discontinued on 2 additional infants who were excessively fussy or cried during testing. Infants were all Caucasian.

4.2.2.2. Apparatus, stimuli and procedure

Infants were tested in the same way as infants in the *Experimenter Change fDL* group, with the exception that the bright background material was changed between the demonstration and test sessions.

4.2.2.3. Results and Discussion

The analysis strategy below follows that used in Experiment 3a. Test sessions were coded in exactly the same way as for Experiment 3. A 2nd independent observer scored a randomly chosen 50% of the sessions. A Pearson product-moment correlation yielded an inter-observer reliability coefficient of 1.00.

Given the small number of participants, and Experiment 3a's findings that the gender of the infant, the particular experimenter who ran the demonstration or test sessions, and the particular background used during the test session did not affect performance, these variables were not analysed in the present Experiment.

Infants exhibited a mean latency of 6.3 seconds (SE = 3.2s) to touch the puppet (see Figure 4.2). An examination of Figure 4.2 reveals that this latency is comparable with those in other conditions from Experiment 3a. Thus, 9-month-old infants were quick to interact with the target stimulus, even after to changes in social and local physical context.

Infants in the *Experimenter and Background Change* group produced an average of 1.08 actions (*SE* = 0.26; presented in Table 4.1 for comparison). The patterns of performance of individual infants making up the mean score are presented in Table 4.2 for comparison. The mean score of the *Experimenter and Background Change* group was significantly greater than the mean score of infants in the *Baseline* condition (taken from Experiment 3a: t (19) = 2.97, p = 0.01). Nine-month-old infants were, therefore, able to retrieve their memories for the deferred imitation task in the absence of both the experimenter and the distinctive background present during the demonstration session. It thus seems unlikely that 9-month-olds succeeded in the *Experimenter Change fDL* condition in Experiment 3a by relying on the distinctive physical context. Rather, by 9-months of age infants do not require congruency in either local physical or social context to access their memory in the deferred imitation task.

4.2.3. Experiment 3c: The effect of location of familiarisation with the experimenter

By 9-months, infants appear to be able to retrieve their memories across changes in both social and local physical context. However, younger infants may be more constrained by contextual congruency between encoding and retrieval: in Experiment 3a, memory retrieval was precluded by a change of social context for 6-month-old infants. This inability to retrieve memory across a change in experimenter is especially interesting as infants were given the opportunity to form an association between the two experimenters during both the familiarisation session and the retention interval. Research with animals shows that when two stimuli are concurrently active in memory, they are likely to be associated together (Dwyer, Mackintosh & Boakes, 1998; reviewed by Hall, 1996). Studies with human infants have demonstrated that 6-month-olds can form an association between two objects, which can later cue retrieval (Barr, Marrot & Rovee-Collier, 2003; Campanella & Rovee-Collier, 2005). For example, Barr *et al* (2003) exposed infants to puppet A and puppet B in a distinctive context for an hour a day for a week. Subsequently, infants saw a sequence of actions demonstrated with puppet A. Infants that had received the pre-exposure to the two puppets exhibited deferred imitation with puppet B, whereas infants who had been pre-exposed to the puppets at different times of day did not. Presumably, associating puppets A and B meant that puppet B activated the representation of puppet A during the test session, in turn cuing memory for the target actions

Given that just 2 minutes of exposure has been sufficient for the formation of an association in previous research (Cuevas, Rovee-Collier, & Learmonth, 2007), and that in Experiment 3a the experimenters were encountered together for 15 minutes prior to the test (5 minutes prior to the demonstration, and 10 minutes during the retention interval), it is surprising that 6-month-old infants did not benefit from the opportunity to form an association between the experimenters in the present study. Six-month-old infants experience difficulty, however, in transferring their knowledge from one physical environment to another (Chapter 3; Hartshorn *et al.*, 1998b; Hayne *et al.*, 2000). It is possible that infants were unable to use the association between the experimenters to cue retrieval in Experiment 3a because the association was formed *in a different room* to that in which the deferred imitation task was carried out. In Experiment 3c a group of infants were tested in an Experimenter Change condition, in which they received equivalent exposure to the two experimenters *in the testing room*. If infants are unable to form an association between the two experimenters, or an association is insufficient to support retrieval, this manipulation should have no facilitative effect on memory. However, if infants are able to form an association between the two experimenters that promotes retrieval of memory for the target actions, this association is more likely to be available to infants when it is encoded in the environment in which the deferred imitation session takes place. Thus, retrieval may be facilitated when the two experimenters are encountered in the testing environment prior to the test session.

4.2.3.1. Participants

Twelve 6-month-old infants (6 female and 6 male) were recruited in the same way as for Experiment 3a. Testing was discontinued on 3 additional infants who were excessively fussy or cried during testing. In addition, during testing it emerged that one additional infant had undergone complications at birth, and the data for this infant was also removed. Infants were all Caucasian.

4.2.3.2. Apparatus, stimuli and procedure

These were identical to that used with the *Experimenter Change fDL* group in Experiment 3a, except that for the *Experimenter Change fSL* group, parents and infants participated in the usual greeting and consent phase of the study with both experimenters in the Experimental Room rather than in the Reception Room. After approximately 5 minutes had elapsed, the second experimenter left the room and the first experimenter began the demonstration session. As in all other conditions, infants returned to the Reception Room for the duration of the retention interval, during which time they interacted with both experimenters. Only the second experimenter was present during the test session. Thus, the only difference between the procedures employed for infants in the *Experimenter Change fSL* and *fDL* groups was whether the initial 5-minute exposure session to the two experimenters took place in the same location as the deferred imitation paradigm (*fSL*), or in a different location (*fDL*).

4.2.3.3. Results and Discussion

The analysis strategy below follows that used in Experiment 3a. Test sessions were coded in exactly the same way as for Experiment 3a. A 2nd independent observer scored a randomly chosen 50% of the sessions. A Pearson product-moment correlation yielded an inter-observer reliability coefficient of 1.00.

Given the small number of participants, and Experiment 3a's findings that the gender of the infant, the particular experimenter who ran the demonstration or test sessions, and the particular background used during the test session did not affect performance, these variables were not analysed in the present Experiment.

Infants exhibited a mean latency of 9.2 seconds (SE = 3.2s) to touch the puppet Examination of Figure 4.2 reveals that this latency is comparable to those in other conditions.

Infants in the *Experimenter Change fSL* group produced an average of 1.17 actions (*SE* = 0.24; presented in Table 4.1 for comparison). The patterns of performance of individual infants making up the mean score are presented in Table 4.2 for comparison. Infants in the *Experimenter Change fSL* condition showed significant levels of imitation compared to the *Baseline* condition in Experiment 3a (t (12) = 4.303, $p <$ 0.001), indicating memory for the target actions. In order to ascertain whether the location in which infants were familiarised with the two experimenters had a significant impact on imitation of the target actions, the number of target actions produced by 6-month-old infants in the *Experimenter Change fSL* (present experiment) and *fDL* (Experiment 3a) conditions were compared with a further two-tailed independent-samples t-test. This revealed that infants in the *Experimenter Change fSL* condition produced significantly more target actions than infants in the *Experimenter Change fDL* condition (t (18) = 3.351, p = 0.004).

Thus, 6-month-old infants who were exposed to both experimenters in the deferred imitation location demonstrated evidence of memory retrieval across a change of experimenter, whereas infants who received the same exposure period in an alternate location did not. Infants in the *Experimenter Change fSL* condition may have been able to retrieve their memory for the association between the experimenters during the test session, and use that association to cue memory of the target actions.

4.2.4. Discussion of Experiment 3

In Experiment 3, 6- and 9-month-old infants remembered and imitated a sequence of target actions over a ten-minute delay when the demonstration and test sessions were conducted by the same experimenter. Similarly, a change in the colour and pattern of a distinctive visual surround between encoding and retrieval had no effect on memory. These findings provide converging evidence that local physical context does not provide essential retrieval cues for 6- and 9-month-old infants in a deferred imitation task (Learmonth *et al.*, 2004).

In contrast, when 6-month-old infants were tested by a different experimenter, retention was only seen when both experimenters had previously been encountered in the location of testing (Experiment 3c). The ability to remember in the presence of different people is, therefore, relatively fragile at 6-months. This does not appear to be the case for older infants. For example, in Experiment 3b, 9-month-old infants showed evidence of imitation when both the background and the experimenter were changed, demonstrating a strong ability to retrieve memories across changes in local features of the test setting. Thus, there appear to be age-related changes in the influence of a change of social context on performance in the deferred imitation paradigm between 6- and 9-months.

Further pursuing the effect of social context on memory retrieval in 6- and 9-month-old infants may reveal more about the nature of the development of contextual influences on memory. One way to do this is to assess memory retrieval with another paradigm. A recognition memory measure may be particularly suitable, because previous work with infants has demonstrated that recognition memory measured by preferential looking tasks is influenced by social factors during learning (e.g., Cleveland & Striano, 2006). Exploring the effect of social context on recognition memory may provide useful information about the role of social cues during memory retrieval.

4.3. Experiment 4: The effect of a change of social context on recognition memory

Experiment 4 explored the role of social context in recognition memory in 6- and 9-month-old infants. To allow the findings of Experiment 4 to be integrated with those of Experiment 3, a modified version of the VPC was used, which will be termed the puppet-VPC (Gross, Hayne, Herbert & Sowerby, 2002). In the puppet-VPC, the 'familiarisation' period was identical to the demonstration session of the deferred imitation task. During the test session, recognition memory for the demonstration puppet was measured by presenting the infant with a familiar and a novel puppet. Behaviour was interpreted in the same way as the standard VPC paradigm (as in Chapter 3). In the original study to use this procedure (Gross *et al.*, 2002), 6-month-old infants showed no preference for either puppet when they were presented on a display apparatus, which in the VPC is typically interpreted as reflecting the absence of recognition memory. The authors argue that this reflects differences between the types of memory measured by the VPC and deferred imitation tasks, as the same infants later produced the target actions when allowed to interact with the puppet. However, it may be that the infants simply failed to recognise the puppet in the VPC task *because the experimenter was absent.* When the experimenter later held the puppet for the deferred imitation test, memory was cued and the infants were able to retrieve their memory for the target actions.[7] If this is the case, testing infants with the puppets in the presence of the experimenter should reveal evidence of memory retrieval. Alternatively, if the disparity results from differences in the types of memory tapped by the two paradigms, the presence of the experimenter may have no effect on memory retrieval in the VPC.

The present study used the puppet-VPC with 6- and 9-month-old infants. In the *With Experimenter* condition, the two puppets were presented at test by the experimenter, who held them just out of the infant's reach. In the *Without Experimenter* condition, the puppets were presented at test on a separate display apparatus. Based on the results of Experiment 3a, there may be age-related changes in the ability to retrieve memory in the *Without Experimenter* condition.

Finally, Experiment 4 pursued Gross *et al.*'s proposal that deferred imitation and VPC measures of memory retrieval can be dissociated in 6-month-old infants. A better understanding of the relationship between VPC and deferred imitation would enable a more effective integration of the findings of Experiment 3 and Experiment 4, in addition to providing valuable information about two paradigms that have been widely used to address memory-related questions in infancy. Thus, following Gross *et al.* (2002), infants in the *Without Experimenter* condition in the present study were allowed to interact with the puppet after the paired presentation session, to compare retention using the puppet-VPC procedure to retention in the traditional deferred imitation test.

However, in the light of the possibility that contextual changes between the learning and test sessions influence memory retrieval in the puppet-VPC task, it is possible that infants in the *Without Experimenter* condition would perform differently in the puppet-VPC and imitation tests because the puppet-VPC test session was conducted

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[7] The authors did consider and discount this possibility on the basis of a second group of infants who also showed a null preference despite having viewed the two puppets in the VPC test on the hands of an experimenter. However, in this condition the experimenter was instructed to look down and have no interaction with the infant. The artificiality of this condition may have been an important factor in the lack of recognition displayed. This is elaborated in Section 4.3.5.

in a context that differed more from the learning session than did the imitation test. Whereas the learning session involved the experimenter holding one puppet, as does the imitation test, the puppet-VPC test for the *Without Experimenter* condition involved the presentation of two puppets in the absence of the experimenter. To establish the relationship between memory retrieval in the VPC and deferred imitation tests when the contextual elements of the test procedures were identical, infants in the *With Experimenter* condition (where the puppet-VPC involved two puppets presented by the experimenter) were given a deferred imitation test with both puppets after the paired presentation session. This allowed a direct comparison of memory retrieval in the two paradigms.

4.3.1. Participants

Thirty-six 6-month-old infants (18 male) and thirty-six 9-month-old infants (18 male) were recruited in the same way and by the same criteria as for Experiment 3. Testing was discontinued on 6 additional infants who were excessively fussy or cried during testing (two 6-month-old infants and one 9-month-old infant) whose parents attempted to draw their infants' attention toward a particular puppet during the test session (two 6-month-old infants), or who showed side bias during the test session (one 9-month-old infant). Infants were Caucasian (n = 43) and Afro-Caribbean (n = 5) and from families of moderate to high socio-economic status.

4.3.2. Apparatus

The stimuli were two of the hand puppets used in Experiment 3: a grey rabbit and a pink mouse (30 cm in height). The particular puppet employed as the familiar stimulus was counterbalanced across age, gender, and experimental condition. Each puppet served equally as the novel and the familiar stimulus. For infants in the *Without Experimenter* condition, during the test session the puppets were presented on a cardboard display apparatus (92 cm x 34 cm x 58 cm), positioned such that the puppets were approximately 60 cm in front of the infant.

4.3.3. General Procedure

Infants were tested in the laboratory at a time of day that was defined by the caregiver as an alert/play period. Prior to the start of the study, a female experimenter interacted with the caregiver and the infant in the Reception Room for approximately 5 minutes until the infant appeared comfortable with the experimenter. During this time informed consent was obtained from the caregiver. The remainder of the experiment was conducted in an Experimental Room, in which the infant was seated on their caregiver's lap. A warm-up phase was conducted at the start of the study as in Experiment 3 (described in Section 4.2.1.3).

Within each age group, infants were randomly assigned to one of two experimental conditions (*With Experimenter* or *Without Experimenter*), or to the *Baseline* condition (a control condition for the deferred imitation test). There were 6 male and 6 female infants in each group. Infants in the *With Experimenter* and *Without Experimenter* conditions participated in a demonstration session and a puppet-VPC testing session that were separated by a retention interval of approximately 1 minute. This retention interval was chosen to reflect the typical retention interval used in VPC studies. After the puppet-VPC test session, both groups were given a deferred imitation test. Infants in the *Baseline* condition were tested in exactly the same procedure as infants in the *Baseline* condition in Experiment 3a (Section 4.2.1.3.2), except the duration of the retention interval was 2 minutes in the present study. This was to match the time interval that elapsed between the demonstration and deferred imitation test phases for infants in the *With Experimenter* and *Without Experimenter* conditions.

4.3.3.1. Demonstration session

The demonstration session for both experimental groups and the *Baseline* group immediately followed the warm-up phase. These were identical to that used in Experiment 3. After the demonstration session, the infant remained seated in the test room for a 1-minute retention interval whilst the experimenter prepared the stimuli for the test phase, out of the infant's line of sight.

4.3.3.2 Puppet-VPC Test

During the puppet-VPC test session, infants in the two experimental groups were presented simultaneously with the puppet used during the demonstration session, and the second, unfamiliar puppet. Infants' eye movements were recorded by a camera positioned centrally above the puppets. The puppets were displayed to the infant for 60 seconds. In all three conditions, the left-right orientation of the puppets was counterbalanced such that half the infants in each group saw the familiar puppet on the left side, and half the infants saw the familiar puppet on the right side. The way in which the puppets were displayed to the infant differed between conditions (Figure 4.4).

Figure 4.4. Presentation of the novel and familiar puppets in the *With Experimenter* (left) and *Without Experimenter* (right) conditions of Experiment 4.

In the *Without Experimenter* condition, the puppets were presented on a cardboard display apparatus just out of reach of the infant. The experimenter was hidden from the infant for the duration of the test session. In the *With Experimenter* condition, the experimenter presented one puppet on her left hand, and one puppet on her right hand. The puppets were held just out of reach of the infant. The experimenter acted in the same way as during a typical test session for the deferred imitation task. She maintained her head and eyes in a forward looking pose during the entire testing session, to minimise the possibility that the infant's attention was not drawn to either puppet by social cues from the experimenter. The experimenter maintained a mildly positive expression throughout the test session in order that the infant would not be discouraged from paying attention to the puppets by induced negative affect. However, the experimenter did not respond to any attempts to initiate interaction on the part of the infant.

4.3.3.3. Deferred Imitation test

For infants in the *Baseline* condition, and the *Without Experimenter* condition, at the end of the test session the familiar puppet was presented to the infant in the same manner as for the imitation test used in Experiment 3. Infants in the *With Experimenter* condition were presented with both the familiar and novel puppets, one on each hand of the experimenter, but otherwise the procedures used were the same as for the other two groups.

4.3.4. Results

4.3.4.1. Coding the puppet-VPC test

Infants' eye movements during the puppet-VPC test session were coded offline using frame-by-frame analysis of the video recordings. For each 40 ms frame of the test session, the location at which the infant was looking was coded as either the left-hand puppet, the right-hand puppet, the experimenter (if present) or 'elsewhere' (defined as looking at anything other than the puppets, or the experimenter). A second observer coded 50% of the video recordings; a Pearson product-moment correlation across all measures of looking time (to the experimenter, each puppet and elsewhere) yielded an inter-observer reliability coefficient of 0.96. Where discrepancies arose, the score from the first coder was accepted. After the video had been coded, the lateral position of the familiar puppet was looked up in the testing record, and scores were calculated to produce a measure of the duration of time each individual infant spent looking at the novel and familiar stimuli, the experimenter, or elsewhere (Figure 4.5 and 4.6).

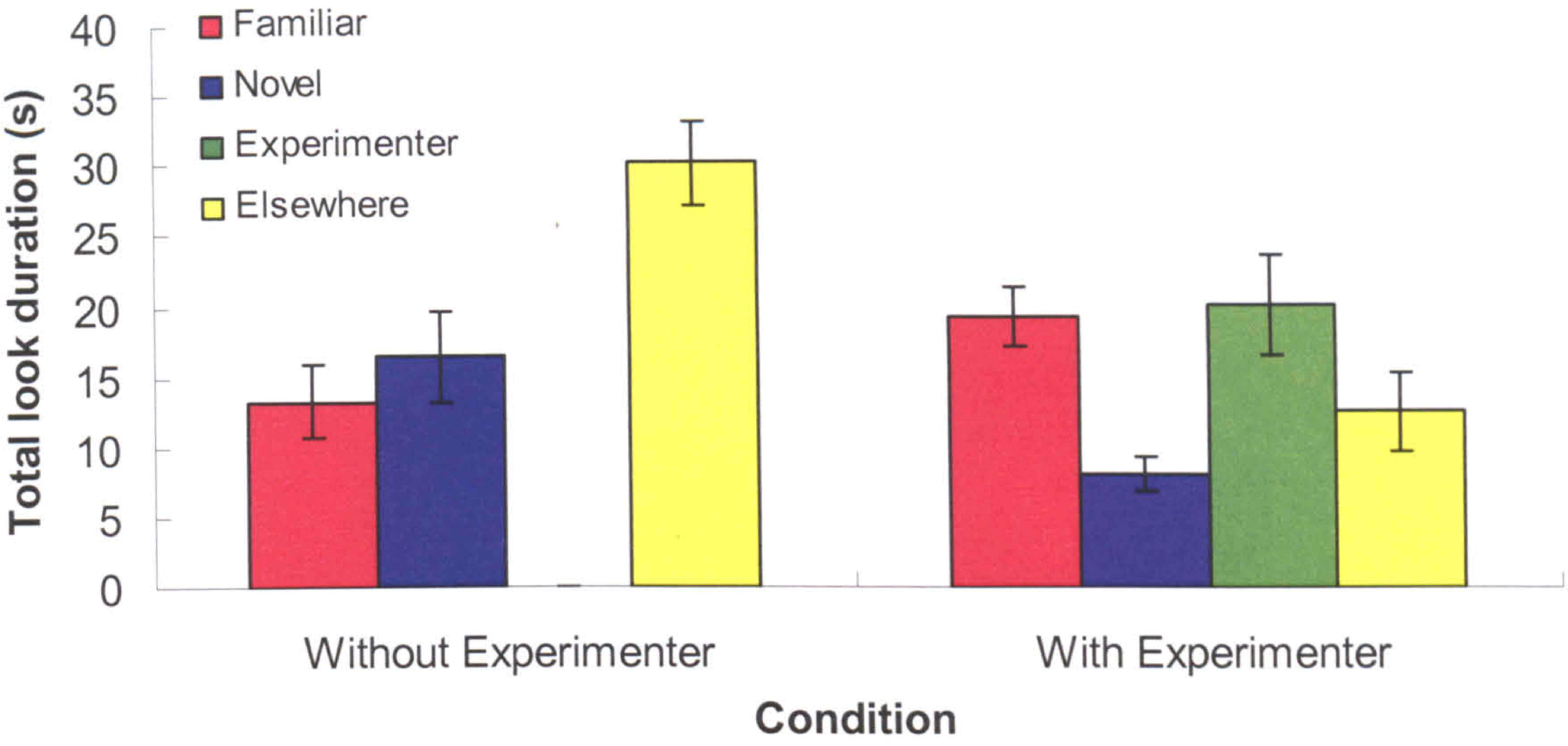

Figure 4.5. Patterns of looking of 6-month-old infants in the puppet-VPC tests in Experiment 4. The mean time 6-month-old infants spent looking at the familiar and novel stimuli, the experimenter, or elsewhere, in the test sessions of the *Without Experimenter* and *With Experimenter* conditions (n = 12 in each condition). Error bars indicate +/- 1 standard error.

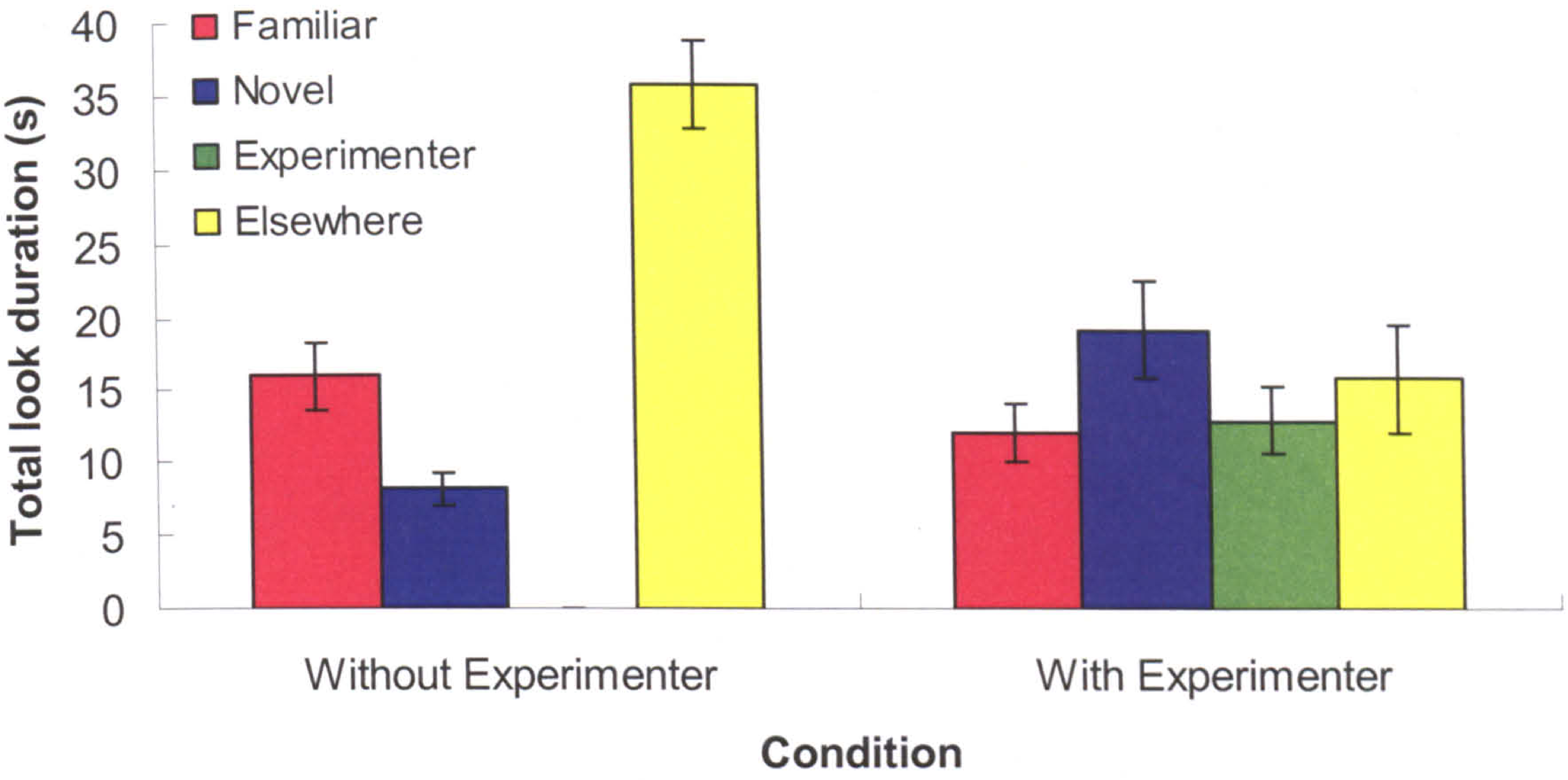

Figure 4.6. Patterns of looking of 9-month-old infants in the puppet-VPC tests in Experiment 4. The mean time 9-month-old infants spent looking at the familiar and novel stimuli, the experimenter, or elsewhere, in the test sessions of the *Without Experimenter* and *With Experimenter* conditions (n = 12 in each condition). Error bars indicate +/- 1 standard error.

4.3.4.2. Coding the deferred imitation test

Behaviour during this period was coded as for the deferred imitation test in Experiment 3a. For infants in the *With Experimenter* condition, who received two puppets during the deferred imitation test, behaviour was coded for each puppet. Thus, infants received two scores, one for the actions they produced on the familiar puppet, and one for the actions produced on the novel puppet.

4.3.4.3. Analysis strategy

The analysis strategy from Chapter 3 was used to assess the influence of social context on recognition memory. Looking times to the novel and familiar stimuli in the puppet-VPC test were converted to novelty scores. Novelty scores were first entered into an ANOVA, to assess differences between groups. Secondly, scores were analysed by comparison to the theoretical 'null preference' of 0.5 in a two-tailed one-sample t-test. This indicates whether individual groups of infants showed evidence of recognition memory. The results of these analyses are presented in Section 4.3.4.4 below. As potential differences in the importance of the experimenter to infants of different ages might be revealed in different patterns of looking to the experimenter during the demonstration and test sessions, this variable was also analysed in a similar manner. These results are presented in Section 4.3.4.5.

The relationship between the puppet-VPC and deferred imitation measures of memory was examined by comparing novelty scores in the VPC to the number of actions infants produced in the deferred imitation test, according to the scoring method outlined in Experiment 3. These results are presented in Section 4.3.4.6 below.

4.3.4.4. Does a change of social context influence memory retrieval in 6- and 9-month-old infants?

Looking times were then totalled across both test periods, to examine whether the groups showed any differences in overall looking time to the test stimuli (Table 4.4).

	With Experimenter	*Without Experimenter*
	Mean total looking time (s)	Mean total looking time (s)
6-month-olds	27.29 (2.57)	29.82 (2.92)
9-month-olds	31.23 (4.38)	24.18 (2.97)

Table 4.4. Looking to the test stimuli in the VPC-puppet test in Experiment 4.
The mean total looking time to the two puppets during the 60-second test session exhibited by each group of infants (n = 12 in each group). Standard errors are shown in parentheses.

An Age (6- or 9-months) x Condition (*With Experimenter* or *Without Experimenter*) ANOVA on total looking times revealed no significant main effects, and no significant interaction (all $p < 0.05$). This confirmed that infants in all groups viewed the test stimuli for comparable lengths of time. Mean novelty scores for each group of infants were then calculated (Figure 4.7). Preliminary analyses confirmed that novelty scores were not significantly influenced by the gender of the infant, the puppet chosen as the familiar stimulus or the lateral position of the familiar stimulus during the test session. Data were thus collapsed across these variables in further analyses.

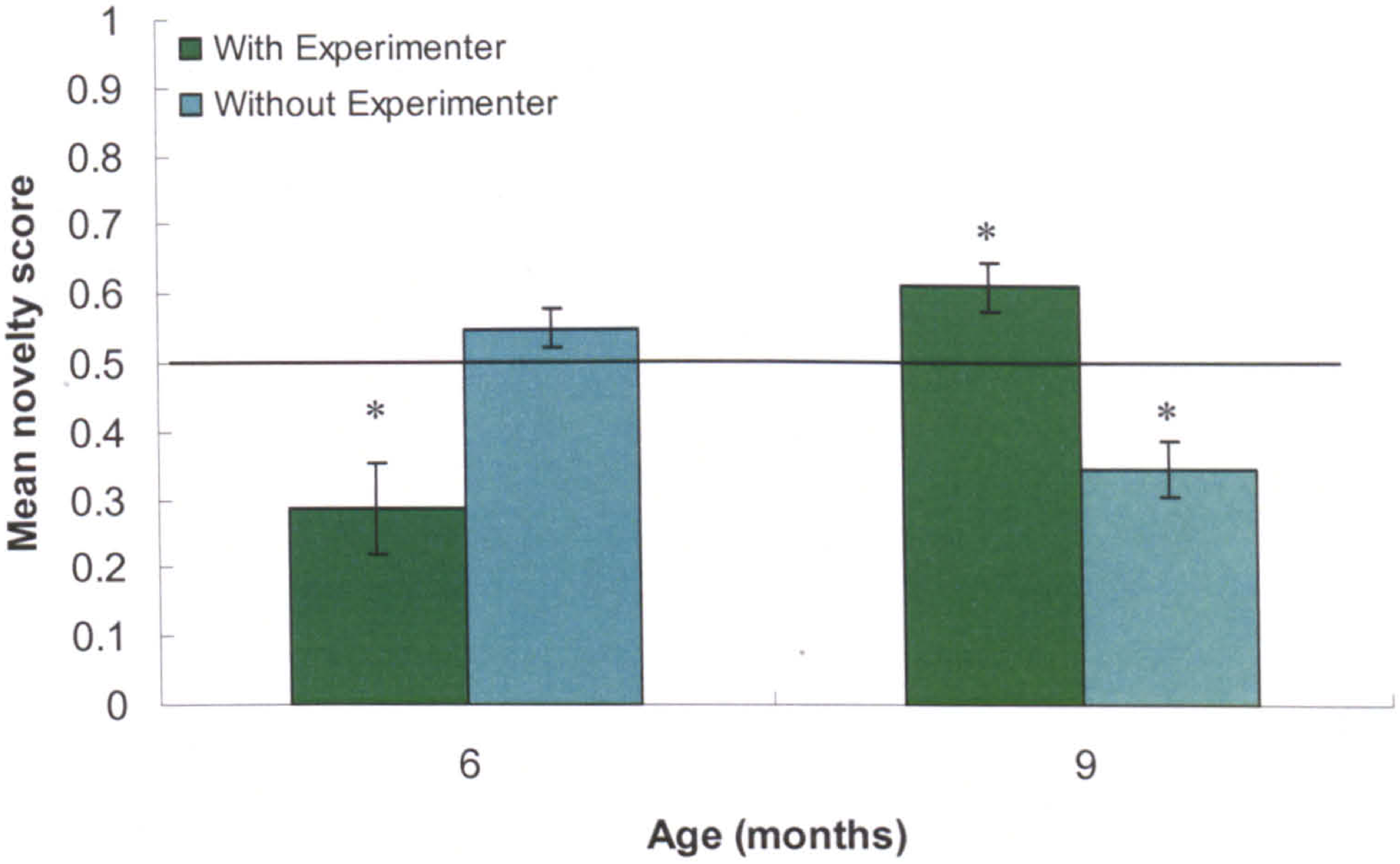

Figure 4.7. The effect of the presence of the experimenter on recognition memory in 6- and 9-month-old infants.
The proportion of total looking time to the puppets that 6- and 9-month-old infants spent looking at the novel stimulus in the *Without Experimenter* and *With Experimenter* conditions (n = 12 in each group). An asterix indicates performance is significantly different from 0.5 (p<0.05). Error bars indicate +/- 1 standard error.

To assess whether there were any differences between the preferences shown by different groups of infants, the novelty scores were entered into a 2 Age (6- or 9-months) x 2 Condition (*With Experimenter* or *Without Experimenter*) ANOVA. This revealed no main effects, but there was a significant interaction between Age and Condition (F (1,47) = 33.117, $p < 0.001$). Examination of Figure 4.7 reveals that 6-month-old infants spent a greater proportion of time looking at the novel stimulus in the *Without Experimenter* condition than they did in the *With Experimenter* condition. In contrast, 9-month-olds spent a greater proportion of time looking at the novel stimulus in the *With Experimenter* condition than in the *Without Experimenter* condition. Thus, the effect of a change of social context on recognition memory was different for 6- and 9-month-old infants.

To establish whether any particular group recognised the familiar stimulus, the novelty scores for each group of infants were compared with a theoretical chance level of 0.5. Six-month-old infants in the *Without Experimenter* condition did not show a significant preference for either stimulus (t (11) = 0.73, *n.s.*), providing no evidence they recognised the familiar stimulus in the absence of the experimenter. In contrast, 6-month-old infants in the *With Experimenter* condition showed a significant preference for the familiar stimulus (indicated by a novelty score that was significantly less than 0.5; t (11) = 6.097, p <0.001). Nine-month-old infants also showed a significant preference for the familiar stimulus in the *Without Experimenter* condition (t (11) = 5.32, p <0.001). Finally, 9-month-old infants in the *With Experimenter* condition showed a significant preference for the novel stimulus (t (11) = 2.708, p = 0.02). Thus, 9-month-old infants recognised the familiar stimulus with or without the presence of the experimenter (although the direction of preference shown differed between the two conditions), whereas the 6-month-old infants only recognised the familiar stimulus when the experimenter was present.

4.3.4.5. Did 9-month-old infants look less at the experimenter during the demonstration or test session than 6-month-olds?

Social context may be more important for memory retrieval for 6-month-old infants because they spend more time looking at the experimenter during the demonstration or test sessions than 9-month-old infants. To establish whether this was the case in the present studies, data from the *With Experimenter* condition were analysed in terms of the mean length of time 6- and 9-month-old infants spent looking at the experimenter and the puppets during the demonstration and test sessions (Figures 4.8 and 4.5/4.6). Data from the demonstration session were coded offline by frame-by-frame analysis of video-recordings in the same manner as data from the test sessions (described in Section 4.3.4.1), except that only looking to the puppet and the target actions, or to the experimenter, was noted. Looking times were not significantly affected by the gender of the infants (all $p > 0.05$), so data were collapsed across this variable.

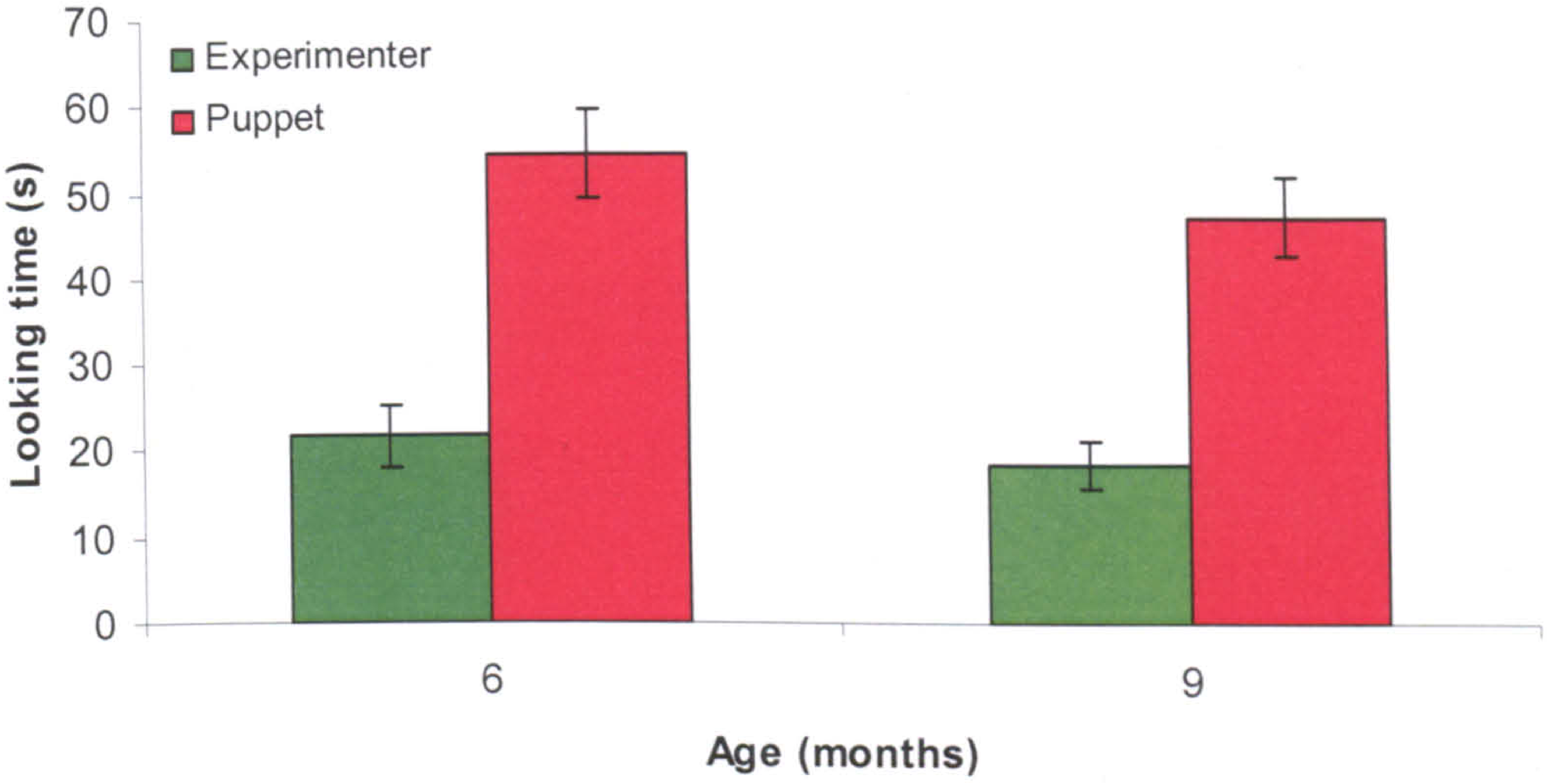

Figure 4.8. Patterns of looking during the demonstration session of the puppet-VPC test in Experiment 4.
The mean duration of time 6- and 9-month-old infants spent looking at the experimenter, or at the puppets, during the demonstration session of the puppet-VPC task. Error bars indicate +/- 1 standard error.

Two-tailed independent-samples t-tests revealed no significant differences in the mean duration of time 6- and 9-month-old infants spent looking at the experimenter during the demonstration session (t (20) = 0.726, *n.s.*), or the total time spent looking at the demonstration as a whole (t (20) = 1.657, *n.s.*). Similarly, two-tailed independent-samples t-tests revealed no significant difference between age groups in the length of time infants looked at the experimenter during the test session (t (22) = 1.71, n.s), or the total time infants spent looking at either the puppets or the experimenter during the test (t (22) = 0.73, *n.s.*).

In order to provide comparability with the analyses above, the same question was also addressed by calculating the proportion of time infants spent looking at the experimenter or at the puppets. This was achieved by summing the total looking time to the puppets or experimenter, and dividing looking time to either the experimenter or the puppets by this sum. Again, two-tailed independent-samples t-tests indicated there were no significant differences in the proportion of time infants in different age groups spent looking at the experimenter during the demonstration (t (20) = 0.08, *n.s.*) or test sessions (t (22) = 1.34, *n.s.*). Thus, it does not seem that social context was more important to 6-month-olds because they look at the experimenter more during the demonstration or test sessions (either in absolute or relative terms) than 9-month-olds.

4.3.4.6. What was the relationship between performance in the puppet-VPC and deferred imitation tests?

4.3.4.6.1. The Without Experimenter Condition

Analyses were first conducted for infants in the *Without Experimenter* group, to establish the relationship between VPC and deferred imitation performance when both test sessions were conducted in the standard manner (the VPC with two puppets and no experimenter, and the deferred imitation task with one puppet held by the experimenter). In this condition, after the 60 seconds of looking time had elapsed, the experimenter removed the familiar puppet from the cardboard display apparatus, out of sight of the infant, and presented it to the infant. The infant was then allowed to interact with the puppet for 90 seconds, as in the standard deferred imitation test. The novel puppet remained out of sight on the cardboard display apparatus. The number of actions each group produced was coded in exactly the same way as for Experiment 3a. Inter-observer reliability calculations produced a product moment correlation coefficient (PMCC) of 0.9 for infants in both groups.

The mean numbers of target actions produced by infants in the *Baseline* and *Without Experimenter* conditions are presented in Table 4.4, and the pattern of scores shown by individual infants that make up this mean are shown in Table 4.5.

	6-month-old infants	*9-month-old infants*
Baseline	0.17 (0.11)	0.08 (0.08)
Without Experimenter Deferred Imitation	1.33 (0.22)	0.83 (0.4)
With Experimenter Deferred Imitation	0.75 (0.28)	0.75 (0.33)

Table 4.4. Mean scores on the deferred imitation tests administered after the puppet-VPC in Experiment 4.
The mean number of actions produced by 6–month-old and 9-month-old infants in the deferred imitation test administered after the puppet VPC (n = 12 in each group). Standard errors are shown in parentheses.

Number of actions (familiar puppet)	*6-month-old infants*	*9-month-old infants*	*Baseline*
0	2	6	11
1	4	2	1
2	6	4	0
3	0	0	0

Table 4.5. Individual performances on the deferred imitation tests administered after the *Without Experimenter* puppet-VPC in Experiment 4, and performance in the *Baseline* condition.
The number of 6- and 9-month-old infants producing 0, 1, 2 or 3 target actions (n = 12 in each group). A score of 1 indicates that the infant removed the mitten, a score of 2 indicates they removed the mitten and either shook or replaced/attempted to replace the mitten, and a score of 3 indicates they performed all three actions.

The same two-stage analysis strategy was used as in Experiment 3a. Imitation scores for infants in the *Without Experimenter* condition were entered into a one-way ANOVA, with Age (6- or 9-months) as the independent variable. The ANOVA indicated that there was no significant difference between the mean number of actions produced by the 6- and 9-month-old infants (F (1,23) = 2.03, *n.s.*).

To determine whether any of the test groups exhibited retention, the mean number of target actions produced by infants in the *Without Experimenter* condition was compared to the mean number of target actions produced by infants in the *Baseline* condition with two-tailed independent-samples t-tests. At both 6- and 9-months of age, infants in the *Without Experimenter* condition produced significantly more target actions than those in the *Baseline* condition (t (22) = 4.642, $p < 0.001$; t (13) = 2.649, p = 0.02). Thus, both 6- and 9-month-old infants showed significant evidence of memory for the target actions when tested by the experimenter in a deferred imitation task, despite the fact that when the same infants were tested in a VPC task in the absence of the experimenter, only the 9-month-old infants recognised the test puppet.

Finally, the relationship between performance in the deferred imitation and VPC tasks was assessed for each age group, following Gross *et al.* (2002). First, the novelty scores exhibited in the VPC task, and the number of actions performed in the imitation test, were correlated with a Pearson product-moment correlation. No significant correlation was found for either the 6- ($r = -0.2$, *n.s.*) or 9-month-old infants ($r = -0.18$, *n.s.*). Second, mean novelty scores were compared for infants who produced no actions and infants who produced at least one action. Again, there were no significant differences in either age group (6-month-olds: $t(10) = 0.43$, *n.s.*; 9-month-olds: $t(10) = 1.19$, *n.s.*). Thus, there was no evidence of a relationship between memory expressed in the VPC task, and memory expressed in the deferred imitation task.

The lack of correspondence in results from the puppet-VPC and deferred imitation tasks for 6-month-olds in the *Without Experimenter* condition replicates Gross *et al.*'s (2002) findings, and is perhaps not surprising in the light of evidence that social context exert strong influences over memory retrieval for this age group. The lack of correlation between puppet-VPC and deferred imitation performance may thus partly be driven by the fact that the experimenter was absent for the VPC test, and present for the deferred imitation test. However, if this is the case, it is intriguing that there was also no correlation in performance for the 9-month-old infants, who were less affected than 6-month-old infants by social contextual congruency between encoding and retrieval in Experiments 3 and 4.

4.3.4.6.2. The With Experimenter Condition

In order to explore further explore the relationship between VPC and deferred imitation measures of memory, results from infants in the *With Experimenter* condition were analysed. Infants in this group received a puppet-VPC and deferred imitation test that were both conducted by the demonstrating experimenter. Furthermore, both involved two puppets being displayed to infants. Thus, the degree of contextual change between the demonstration and test sessions was minor (going from one puppet to two puppets), and identical for the two tests. This was a strong test of the relationship between the VPC and deferred imitation measures of memory, when both were conducted under highly similar conditions.

In the *With Experimenter* condition, after the 60 seconds of looking time had elapsed, the experimenter presented both the familiar and novel puppets to the infant, and allowed them to interact with both puppets for 90 seconds. Behaviour was coded in exactly the same way as for Experiment 3. Target actions were scored the first time they were produced on either puppet, although the puppet upon which each target action was produced was also recorded (Table 4.5). Visual inspection of Table 4.5 reveals that in both age groups, more infants produced target actions for the first time on the familiar puppet than on the novel puppet.

Number of actions	***6-month-olds***		***9-month-olds***	
	Familiar puppet	*Novel puppet*	*Familiar puppet*	*Novel puppet*
0	8	11	6	11
1	1	0	5	0
2	3	1	1	1
3	0	0	0	0

Table 4.6. Individual performances on the deferred imitation tests administered after the *With Experimenter* puppet-VPC in Experiment 4.
The number of 6- and 9-month-old infants producing 0, 1, 2 or 3 target actions. A score of 1 indicates that the infant removed the mitten, a score of 2 indicates they removed the mitten and either shook or replaced/attempted to replace the mitten, and a score of 3 indicates they performed all three actions.

An imitation score was calculated for each infant by summing the number of target actions he or she produced during the test session, regardless of the puppet upon which they were produced (range 0 to 3). Infants received a score of 0 if they touched either puppet, but did not produce any target actions with either puppet. Inter-observer reliability calculations produced a PMCC of 0.92 for infants in both groups. Mean scores for each group were calculated on the basis of the number of target actions infants produced (Table 4.4).

The same two-stage analysis strategy was used to analyse the present data as was used in Experiment 3. Imitation scores were first entered into a one-way ANOVA, with

Age (6- or 9-months) as the independent variable. Table 4.5 presents the individual pattern of scores that make up the mean data. The ANOVA indicated that there was no significant difference between the mean number of actions produced by the 6- and 9-month-olds ($F(1,23) < 0.001$, *n.s.*).

To determine whether any of the test groups exhibited retention, the mean number of target actions produced by infants in the *With Experimenter* condition was compared to the mean number of target actions produced by infants in the *Baseline* condition with independent-samples t-tests. At both 6- and 9-months of age, infants in the *With Experimenter* condition showed a trend towards the production of more target actions than infants in the *Baseline* condition ($t(22) = 1.97, p = 0.06$; $t(22) = 1.94$, p = 0.06), but neither reached conventional levels of significance. This indicates that when both 6- and 9-month-old infants were presented with two puppets, they only showed marginal evidence of deferred imitation. In contrast, the same groups of infants did show evidence of recognition memory for the familiar puppet when this was assessed through a VPC test under highly similar conditions. Again, this suggests there is a dissociation between measures of memory provided by the VPC and deferred imitation tasks.

Finally, the relationship between performance in the deferred imitation and puppet-VPC tasks was assessed for each age group. First, the novelty scores exhibited in the puppet-VPC task, and the number of actions performed in the imitation test, were correlated with a PMCC. No significant correlation was found for either the 6- ($r_S = -0.04$, *n.s.*) or 9-month-old infants ($r_s = -0.167$, *n.s.*). Second, mean novelty scores were compared for infants who produced no actions and infants who produced at least one action. Again, there were no significant differences in either age group (6-month-olds: $t(10) = 0.68, p = 0.515$; 9-month-olds: $t(10) = 0.93, p = 0.378$). Thus, there was no evidence of a relationship between memory expressed in the puppet-VPC task, and memory expressed in the deferred imitation task.

Taken together, the results of the *With Experimenter* and *Without Experimenter* conditions indicate that differences in performance between the puppet-VPC and deferred imitation measures of memory are not solely driven by differences in the role of social context in the two test sessions.

4.3.5. Experiment 4 Discussion

In Experiment 4, 6-month-old infants showed no evidence of recognition memory when the stimuli were presented in the absence of the experimenter. This result replicates Gross *et al.*, (2002). In contrast, 9-month-old infants did show evidence of recognition for the puppet in the absence of the experimenter. This recognition manifested as a familiarity preference. Intriguingly, the 9-month-old infants showed a similar pattern of behaviour in the present study as the 12- and 18-month-old infants in Chapter 3, in that they showed novelty preferences in the *With Experimenter/No Change* condition and familiarity preferences in the *Without Experimenter/ Room Change* conditions respectively. The same explanation can be applied here: when the experimenter was present during retrieval, 9-month-olds had a good memory for the familiar puppet, and were thus interested in visually exploring the novel puppet. In contrast, when the experimenter was absent during retrieval, the change in context between encoding and retrieval caused a mismatch between the contents of memory and the external input, driving a preference for the familiar stimulus.

Intriguingly, the 6-month-old infants showed a familiarity preference in the *With Experimenter* condition. The demonstration session of the puppet task may not have been long enough for 6-month-old infants to become completely habituated to the puppet. In this case, a drive to complete the partial representation of the familiar stimulus may have produced the familiarity preference shown by 6-month-old infants in the *With Experimenter* condition. Nine-month-old infants may learn more quickly in this task, forming a stronger representation of the familiar puppet that drives a novelty preference during the test session. Indeed, 6-month-old infants require 6 demonstrations of the target actions to show memory over a 24-hour retention interval (Barr *et al.*, 1996), whereas 9-month-old infants only require three (Learmonth *et al.*, 2004). Age-related changes in the ability to retrieve memory for the puppet task in the absence of the experimenter may be related to the strength of memory for the puppet itself. When strong, memory persists across an experimenter change; when weak, additional retrieval cues are required from the experimenter. Notably, any change in the strength of the representation of the puppet is not due to differences in the length of time infants of different ages looked at the puppet during the demonstration session (Section 4.3.4.5).

In contrast to the present results, Gross *et al.* (2002) did not find a significant preference when 6-month-old infants were tested by the experimenter. In Gross *et al.*'s study, the experimenter 'lowered her head, breaking all eye contact with the infant', 'extended her arms' and presented the puppets to the infant, moving them 'forwards and backwards at a constant rate' (p 189). It is debatable whether this condition preserves the social context of the learning session, during which the infant can see the experimenter's face, and where eye-contact is frequently made. As faces are particularly salient to infants (reviewed by Slater & Quinn, 2001), it is possible that facial cues are an important component of social context. Indeed, Experiment 3a demonstrated that the identity of the experimenter had an important influence on memory retrieval for 6-month-old infants. Gaze aversion alone can have a negative impact on face recognition for children (Smith, Hood & Hector, 2006) and infants (Farroni, Massaccesi, Menon, & Johnson, 2007). It is possible that when the experimenter lowered her head and broke eye contact with infants in Gross *et al.*'s study, this changed the social context of the task sufficiently for memory retrieval to be precluded for 6-month-old infants. The precise elements of the experimenter's behaviour that are critical for memory retrieval in 6-month-old infants require further investigation.

Finally, Experiment 4 found further evidence for the proposition that performance on deferred imitation and VPC measures can be dissociated (Gross *et al.*, 2002). Even when the stimuli and procedures employed in the VPC and deferred imitation tests were almost identical, there was no correlation between the performance of individual infants on the measures taken to reflect memory retrieval in the two tasks.

4.4. General Discussion

The present study explored the role of physical and social context on memory retrieval in 6- and 9-month-old infants. Although a change of distinctive background did not influence memory retrieval for 6- or 9-month-old infants in a deferred imitation task, a change of social context precluded memory retrieval for 6-month-old infants in both a VPC and deferred imitation task. However, for 9-month-olds, memory was not precluded by a change of social context in either procedure. This was not because 9-month-olds spent less time than 6-month-old infants looking at the experimenter during the learning or test sessions. Nine-month-old infants expressed memory differently across a change of social context in the VPC task, confirming that they encoded the experimenter in memory. Further, the fact that a change of social context precluded memory retrieval for 6-month-old infants in both the puppet-VPC (Experiment 4) and deferred imitation tasks (Experiment 3a) suggests that social context has a particularly pervasive influence on memory retrieval in infancy. That there was no correlation between scores on the VPC and deferred imitation tasks indicates this does not reflect the effect of social context on a third variable that links the two procedures. Furthermore, the fact that 9-month-old infants showed evidence of memory across a change in social context in both paradigms provides converging evidence that there are important changes in the role of social context in memory retrieval between 6- and 9-months. Converging evidence from two paradigms suggests that social context exerts an important but decreasing influence on memory retrieval over the first year of life. These results raise several issues, which will be discussed below.

4.4.1. Why does local physical context appear to be unimportant in the deferred imitation paradigm?

In the present study, a change of distinctive visual background did not influence memory retrieval in 6- or 9-month-old infants. Similarly, Learmonth *et al.* (2004) found that 6- and 9-month-old infants were able to retrieve their memories across a change in the colour and pattern of a distinctive mat upon which they were seated. Thus, there is converging evidence that memory retrieval in the deferred imitation task is not dependent on local physical cues, even when those cues provide a brightly coloured background that is in the infant's line of sight at all times whilst they are participating in the deferred imitation task.

Why is the deferred imitation paradigm less sensitive to a change of local physical context than the VPC or mobile tasks? Contrary to our original hypothesis, the positioning of the local physical context in relation to the stimulus does not seem to be a determining factor. Rather, in the light of the results of Experiment 4, it seems likely that the salience of the experimenter in the deferred imitation task used by Learmonth *et al.* (2005) and in the present study overshadowed local physical cues such as a distinctive visual background for 6-month-old infants (Learmonth *et al.*, 2004). In paradigms such as the standard version of the VPC, or the mobile task, the background or the crib liner is unlikely to be overshadowed because it is the only contextual feature close to the target object. If different types of 'context' have different effects on retrieval in different paradigms used to assess infant memory, it is important to qualify conclusions about the role of 'context' in 'infant memory' (e.g., Amabile & Rovee-Collier, 1991; Boller & Rovee-Collier, 1992; Boller, Rovee-Collier, Gulya & Prete, 1996; Borovsky & Rovee-Collier, 1990; Butler & Rovee-Collier, 1989; Hartshorn *et al.*, 1997, 1998b; Rovee-Collier *et al.*, 1985).

4.4.2. Can performance explanations account for the effects of social context?

Learmonth *et al.* (2005) argue that a change of experimenter precludes memory retrieval because infants show 'social neophobia'. Indeed, their findings show that a wholly novel experimenter impedes infants' ability to retrieve memory for a deferred imitation task, and a five-minute familiarisation period can offset this effect. This accords with research on stranger wariness (e.g., Rheingold & Eckerman, 1973), which indicates that a short period of familiarisation with an experimenter is required to attenuate stranger fear. Thus, the familiarity of the experimenter is important in ensuring that infants are able to express their memories. However, the familiarity of the experimenter cannot account for the influence of social context in the present study. In Experiment 3, 6-month-old infants were unable to retrieve memory across a change in experimenter when they had previously encountered that experimenter for a total of 15 minutes prior to the test session, unless 5 minutes of that encounter occurred in the testing room. Although it could be argued that infants did not view the second experimenter as familiar when they had previously encountered in them in a different room, this seems unlikely, as there was no significant difference in latency to interact with the puppet in the two conditions, and stranger wariness is defined as "the tendency to inhibit approach or to avoid novel objects and persons" (Sroufe, 1977, p.732). Furthermore, stranger wariness increases between 6- and 9-months (e.g., Emde *et al.*, 1976; Waters *et al.*, 1975), whereas in the present study the effect of a change of experimenter on memory retrieval decreased across the same age range. This makes it unlikely that the two are directly related. Finally, social neophobia cannot account for the results of Experiment 4, in which 6-month-old infants did not show evidence of memory retrieval in the *absence* of the experimenter. Thus, whereas the familiarity of the experimenter may play a role in memory retrieval, it cannot account for all the influences social context exerts on retrieval.

Could social context be important because the infant is responding to subtle cues from the experimenter (sometimes termed the' observer-expectancy' effect)? The phenomenon of Clever Hans, the horse who could count, was debunked when a different experimenter tested the horse's prowess. When the horse's trainer was not present, the horse could no longer respond to the arithmetic questions posed (Pfungst, 1965). Although it is important to consider the unconscious signals the experimenter may provide in any study, the present results cannot be explained in this manner. If the experimenter was unconsciously reinforcing looking behaviour during the puppet-VPC task, it seems unlikely that her actions would produce a preference for the familiar puppet in 6-month-old infants, but a preference for the novel puppet in 9-month-olds. Furthermore, four different experimenters were involved in Experiment 3, and preliminary data analyses confirmed that performance did not differ between experimenters. Two of these experimenters were novices at the start of the study, and two were experienced with the puppet task. If subtle cues influence performance, it might be expected that different experimenters would influence behaviour to different extents. This was not the case. Finally, 9-month-old infants were able to recognise the puppet in the absence of the experimenter. Thus, even if 6-month-old infants required influence from the experimenter to show a preference for one of the stimuli, by 9-months infants are not constrained by this requirement, still indicating age-related changes in the importance of the experimenter during memory retrieval.

4.4.3. *Social context influences memory retrieval*

By the logic of the Encoding Specificity Principle (ESP; Tulving & Thompson, 1973), it appears that both 6- and 9-month-old infants encoded details of the experimenter into their memory representations, and associated memory for the experimenter with memory for the puppet (Experiment 4). This provides further evidence that social information plays an important role in learning and memory in the infancy period (e.g., Bigelow & Birch, 1999; Bornstein *et al.*, 2004; Cleveland & Striano, 2004, 2007). However, the presence of the same experimenter during the learning and test sessions was more important for memory retrieval for the 6- than the 9-month-old infants in both paradigms used, indicating that there are broad age-related improvements in generalisation across a change of social context during the first year of life. Thus, age-related changes in contextual influences on memory retrieval are not restricted to physical context features, but also extend to the social domain. Indeed, social context may be so salient that it overshadows other contextual features, such as a distinctive background (Section 4.4.1). The present study shows that with age, social context exerts a smaller influence over memory retrieval, such that infants are more likely to remember what someone has taught them when that person is absent.

4.4.3. Why did the location in which the two experimenters were encountered influence memory retrieval in 6-month-old infants?

Experiments 3 and 4 provide converging evidence that 6-month-old infants require an activated representation of the demonstrating experimenter to retrieve their memory for the puppet or the puppet task. However, the results of Experiment 3b suggest that this activated representation can be provided by a memory of the demonstrating experimenter, and not just her physical presence (as is the case for other stimuli in previous research: Barr, Viera & Rovee-Collier, 2001, 2002; Barr *et al.*, 2003; Campanella & Rovee-Collier, 2005; Cuevas *et al.*, 2007). In the present study, infants may have formed an association between the experimenters during the initial encounter. When this encounter occurred in the location of testing (the *Experimenter Change fSL* condition), the test experimenter later cued retrieval of memory for the first experimenter, rendering memory for the target actions accessible. As memory in 6-month-old infants is constrained by aspects of the global environment (Hartshorn *et al.*, 1998b; Hayne *et al.*, 2000; Chapter 3), this association may not have been available to infants when they were tested in a different location (*Experimenter Change fDL*), rendering them unable to retrieve their memories for the target actions.

By showing that infants can form and utilise an association between two experimenters, the present study adds to previous evidence that infants can associate together physical objects such as two puppets (Barr *et al.*, 2003), a puppet and the train task (Barr *et al.*, 2001), or a mobile and a distinctive context (Cuevas *et al.*, 2007), and use such associations to provide retrieval cues. Seemingly, memory retrieval in infancy requires the activation of the representations of multiple retrieval cues that were present during learning, but those representations do not have to be activated by physically present stimuli. Rather, they can be activated by association to physically present stimuli, provided the memory for the association itself can be retrieved. Thus, 6-month-old infants are able to transfer their knowledge across context changes, provided they have an opportunity to form associations between the cues present during learning and retrieval in the location of testing (Cuevas *et al.*, 2007).

The studies in this Chapter reveal that the influence of a change of social contextual information decreases over the first year of life, as does the influence of a change of global physical context (Chapter 3). By 12-months, infants require little extrinsic contextual support for memory retrieval. The next Chapter explores the role of details of the central stimulus (intrinsic context) in memory in 12-month-old infants.

Chapter 5: Investigating the factors that facilitate generalisation across a form change in 12-month-old infants

5.1. Introduction

The aim of this study was to investigate the factors that influence generalisation across changes in features of the stimulus (intrinsic context), at the end of the first year of life.

5.1.1. Facilitating generalisation in infancy

Although infants readily generalise across changes in social and physical extrinsic context by the age of 12-months, the ability to generalise across a stimulus change remains limited in this age group (Butler & Rovee-Collier, 1989; Hayne et al., 1997; Herbert & Hayne, 2000b; Hill *et al.*, 1988; Learmonth et al., 2004). Factors that facilitate stimulus generalisation in 12-month-olds may have a particularly large effect on their ability to use their experiences to guide future behaviour. Identifying such factors may reveal the parameters that control the influence of stimulus features on memory retrieval in infancy.

Little is known about facilitating generalisation in 12-month-old infants. A range of manipulations are known to facilitate generalisation for 3- and 6-month-old infants, such as exposing infants to more than one stimulus during learning (Muzzio & Rovee-Collier, 1996), or pre-exposing infants to the demonstration and test stimuli before the demonstration session (Barr *et al.*,2003; Campanella & Rovee-Collier, 2005). However, these manipulations have not been tested with older infants. One experience that is effective in facilitating generalisation in a deferred imitation task for 12- and 18-month-old infants is the opportunity to practice the actions immediately after learning (Hayne, Barr & Herbert, 2003; Learmonth *et al* 2004). Thus, physical experience of the target actions during the learning session facilitates the subsequent generalisation of those actions to a related stimulus. However, infants may not always have the opportunity to learn through practice. Furthermore, tasks involving motor practice may utilise additional, or different, brain systems in memory processing (reviewed by Squire, 2004).

Only one manipulation is known to facilitate generalisation in the absence of physical practice for infants older than 6-months. Verbal cues during retrieval facilitate generalisation for 24-month-old infants, but not for 18-month-old infants (Herbert & Hayne, 2000a). Thus, verbal cues may help infants to apply their previous experiences to a novel stimulus, but not until between 18- and 24-months. No studies have been conducted into facilitation of generalisation in purely observational learning paradigms with infants aged between 6- and 18-months, leaving a large gap in knowledge about the factors controlling generalisation in infancy.

5.1.2. The present study

The present study explored a series of variables that might facilitate generalisation across a stimulus change in 12-month-old infants in the absence of physical experience during learning. The puppet deferred imitation task is ideally suited to addressing this question, because 12-month-old infants show evidence of memory in this task when learning occurs through observation alone. Furthermore, previous research with the puppet task indicates that 12-month-old infants can generalise across a change in stimulus colour, but not a change in stimulus form, over a ten-minute delay (Hayne *et al.*, 2000), raising the possibility that generalisation across a change of form could be facilitated for this age group. Importantly, this change in form involves a perceptual change that does not alter the appearance or operation of the functional parts of the stimulus. In Experiment 5, manipulations were chosen that had been successful in promoting generalisation in different tasks, or with different age groups. Experiment 6 assessed the role of extrinsic contextual information in generalisation across a form change.

5.2. Experiment 5: Variations in the encoding session

The stimulus change used in this Experiment was a change in the form of the puppet used in the puppet task (Figure 5.1). Groups of 12-month-old infants were given increased or more varied learning experiences during the demonstration session, to establish whether generalisation across a form change could be facilitated. Performance was compared with that of a group of infants tested with the learning stimulus, the *2A* group.

Figure 5.1. The grey rabbit and the grey mouse, an example of the form change employed in Experiments 5 and 6a.

5.2.1. More opportunities to learn: Massed (4A) or distributed (2A-2A) learning

Increasing the number of repetitions of the target actions within the demonstration session influences retention duration for 6-month-old infants (Barr *et al.*, 1996), and ordered recall after a long delay for 9-month-old infants (Bauer, Wiebe, Waters & Bangstom, 2001). Thus, the *4A* condition was designed to assess whether doubling the number of demonstrations of the target actions (from two to four) would facilitate 12-month-old infants' generalisation. If doubling the number of demonstrations facilitated generalisation, this might imply that trace strength is an important variable in determining generalisation in infancy.

Increasing the number of demonstrations may, however, result in the infants becoming disinterested in (or habituating to) the target actions. The spacing of demonstrations within the session therefore also needs to be considered. In variability training with the mobile task, for example, the timing of exposure is important in facilitating generalisation (Merriman, Rovee-Collier & Wilk, 1997). In this study, having a gap between the two training sessions allowed variability training to be effective for 3-month-old infants after a 24-hour delay. When the same amount of training was provided continuously without a break, infants showed no generalisation. Including a gap half way through the demonstration session may also impact on generalisation in the deferred imitation task. The shorter learning session (30 seconds for two demonstrations in the deferred imitation task; 18 minutes of training in the mobile task for 3-month-olds), and shorter retention interval (ten minutes), in the present study resulted in the use of a brief pause halfway through the demonstration session. Thus, infants in the *2A-2A* condition saw two sets of two demonstrations, separated by a 10-second pause. This might redraw infants' attention to the puppet, potentially facilitating learning and generalisation. Again, successful facilitation may imply a role for memory strength in generalisation.

5.2.2. Variability training: Colour variation (2A'2A) or Form and colour variation (2Y2A)

Variability training (training with more than one stimulus) effectively promotes generalisation across a cue change for 6-month-old infants in the mobile task (Muzzio & Rovee-Collier, 1996; Shields & Rovee-Collier, 1992). If the effects of variability training are not dependent on physical experience, then this procedure might facilitate generalisation by 12-month-olds. In the *2A'2A* variability training group, infants saw two demonstrations with each of two puppets that were of the same form but different colours. Infants were tested with a puppet that was a different form but the same colour to the second demonstration puppet, as for infants in the *2A*, *2A-2A* and *4A* conditions. Twelve-month-old infants in the *2A'2A* condition might be able to use their ability to generalise across a colour change (Hayne *et al.*, 1997) to form a 'puppet' category during learning, helping them to generalise more readily across a form change.

However, exposing infants to two puppets of the same form during the demonstration session may encourage infants to focus on this dimension, reducing their ability to generalise across a form change. Thus, infants in the 2Y*2A* condition saw two demonstrations with each of two puppets that were of different forms and different colours. Infants were tested with a puppet that was of a different form to, but the same colour as, the second demonstration puppet, as in the *2A'2A* condition. This may encourage infants to focus on a dimension other than the form of the puppet, thus facilitating generalisation to the third puppet during the test session. Indeed, increasing the perceptual variability of a stimulus set can facilitate generalisation to novel exemplars in an object examination task (Oakes, Coppage, & Dingel, 1997).

5.2.3. Participants

Eighty-four 12-month-old infants (42 female) were recruited from a database of infants born at the Jessop Maternity Ward of the Hallamshire Hospital, Sheffield. Infants were tested within ten days of their 12-month-old birthday. No infant was born more than 3 weeks premature, or had experienced any birth complications. Testing was discontinued on additional infants who were excessively fussy or cried during testing (*n* = 7) or failed to interact with the experimenter during the warm-up phase described below (*n* = 7). All infants were Caucasian.

5.2.4. Apparatus

The stimuli were identical to those used in Chapter 4, Experiment 3 (see Section 4.2.1.2). A dark grey koala and a dark brown kangaroo (30 cm in height) were also used in the *2Y 2A* condition described below.

5.2.5. General procedure

Infants were randomly assigned to one of six demonstration conditions (*n* = 72; 6 females, 6 males per group) or a *Baseline-NC (*No Change) condition (*n* = 12; 6 females, 6 males). The general procedural details of the demonstration, retention interval and test sessions were the same as those used in Chapter 4, Experiment 3 (see Section 4.2.1.3), apart from the number of times the target actions were performed, and the particular stimuli on which they were performed. These details are summarised in Table 5.1 for each demonstration group. The procedure used for the *Baseline-NC* condition was the same as that used for infants in the *Baseline* condition in Chapter 4, Experiment 3 (see Section 4.2.1.3.2), except in the present study infants saw the *Baseline* demonstration four times.

Group Name	***Demonstration Session***	***Test Session***
2A-NC	2 demonstrations puppet A	Puppet A
2A	2 demonstrations puppet A	Different Form to puppet A
4A	4 demonstrations puppet A	Different Form to puppet A
2A-2A	2 demonstrations puppet A, 10 s no puppet, 2 demonstrations puppet A	Different Form to puppet A
2A' 2A	2 demonstrations (different colour to puppet A), 2 demonstrations puppet A	Different Form to puppet A
2Y 2A	2 demonstrations (different colour and form to puppet A), 2 demonstrations puppet A	Different Form to puppet A
Baseline-NC	4 Non-demonstrations puppet A	Puppet A

Table 5.1. The demonstration and test session stimuli used for each group of infants in Experiment 5. '2 demonstrations' indicates that infants saw the set of three target actions demonstrated twice. The procedure for 'non-demonstrations' is detailed in Section 4.2.1.3.2. NC = no change.

5.2.6. Results and Discussion

The entire test session was videotaped for subsequent analysis. One observer scored the presence or absence of three target behaviours during the test: (a) remove the mitten, (b) shake the mitten, (c) replace, or attempt to replace, the mitten. Infants were allowed 90 seconds from the time they first touched the stimulus to produce the target actions. A 2nd independent observer scored a randomly chosen 50% of the sessions. A Pearson product-moment correlation yielded an inter-observer reliability coefficient of 0.96.

An imitation score was calculated for each infant by summing the number of target behaviours he or she produced during the test session (range 0 to 3). Infants were only given credit for the first time they produced each target action. Preliminary analyses confirmed that scores were not influenced by the gender of the infant, the particular stimulus used during the demonstration session, or the particular stimulus used during the demonstration session (all p>0.05), and so further analyses were collapsed across these variables.

The mean number of actions produced by each group of infants is shown in Figure 5.2. Table 5.2 shows the patterns of performance of individual infants making up the mean scores.

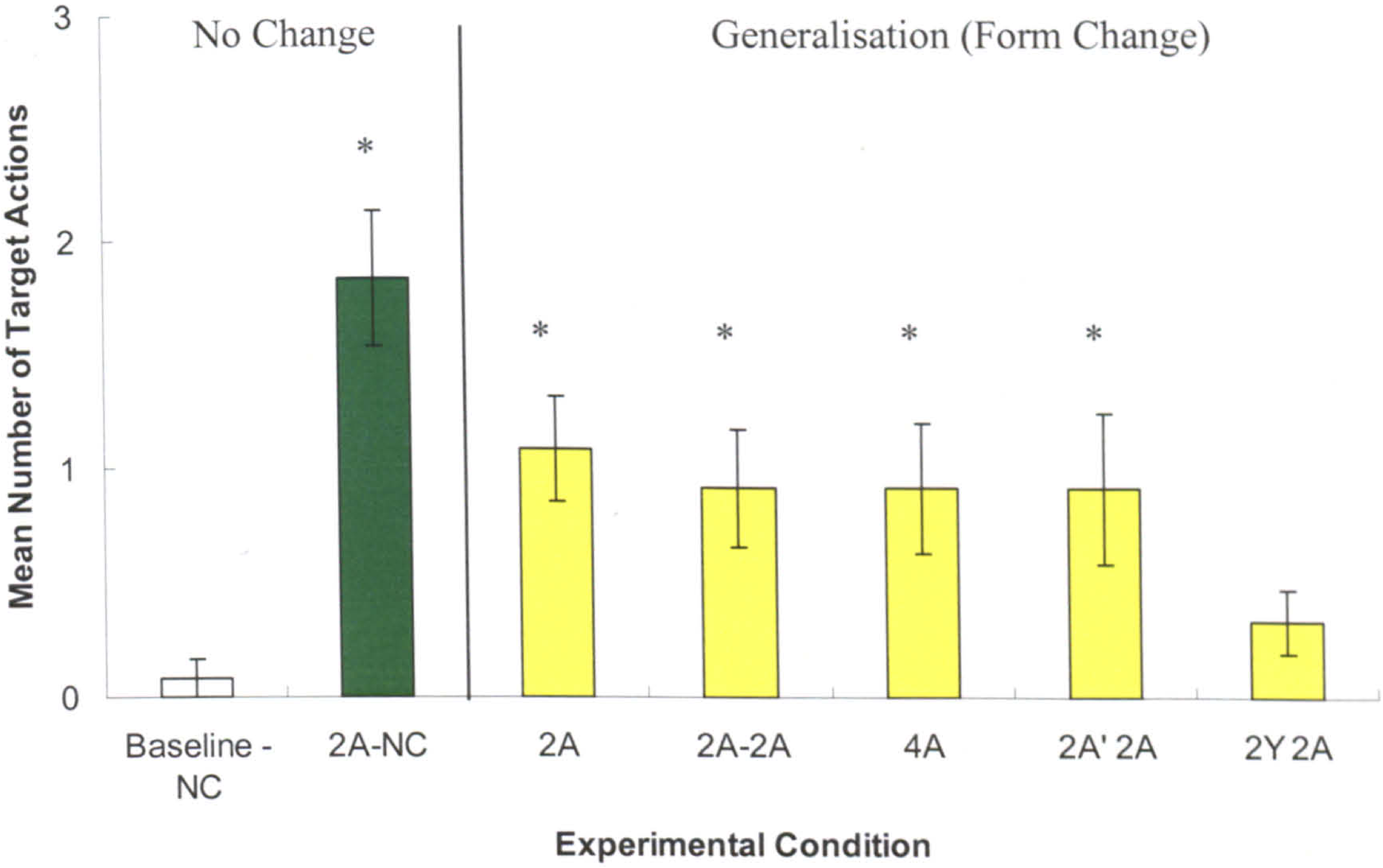

Figure 5.2. The effect of encoding variation on generalisation in 12-month-old infants.
The mean number of target actions (+/- 1 Standard Error) produced by each group of infants (n = 12 in each group) as a function of variations in the encoding session, and the stimulus used during the test session. An asterix indicates that the group imitation score is significantly greater than that of the *Baseline* group (p<0.05). NC = no change.

Number of actions	*0*	*1*	*2*	*3*
Baseline-NC	11	1	0	0
2A	3	5	4	0
2A-2A	5	3	4	0
4A	6	1	5	0
2A'2A	7	0	4	1
2Y2A	8	4	0	0
2A-NC	2	1	6	3

Table 5.2. The number of 12-month-old infants producing 0, 1, 2 or 3 target actions in each condition in Experiment 5.
A score of 1 indicates that the infant removed the mitten, a score of 2 indicates they removed the mitten and either shook or replaced/attempted to replace the mitten, and a score of 3 indicates they performed all three actions.

An initial two-tailed independent samples t-test compared the number of target actions produced by infants in the *2A-NC* and *2A* groups. This confirmed that the number of target actions produced was significantly greater when infants were tested with the original demonstration stimulus than when they were tested with one that differed in form (t (22)=1.999, $p = 0.05$). A change of form had a significant effect on memory retrieval.

To assess whether there were any differences in imitation across a change in form as a function of experiences during the encoding session, the data from the five form change demonstration groups were subjected to a one-way between-subjects Analysis of Variance (ANOVA). This analysis revealed no significant main effect of group, indicating that manipulations of the stimuli seen during the encoding session had little effect on generalisation (F (4,59) = 1.24, *n.s.*).

To assess whether any of the demonstration groups remembered the target actions, the mean number of target actions produced by each group was compared to the number of target actions spontaneously produced by infants in the *Baseline-NC* group using two-tailed independent samples t-tests. These analyses indicated that infants exhibited significant levels of retention in the group tested with the demonstration puppet (*2A-NC*: $t(13) = 5.668, p < 0.001$), and in all but one of the groups tested with a puppet of a different form: *2A*: t (12) = 4.105, $p < 0.001$; *2A-2A*: t (13) = 3.053, $p = 0.009$;

2A' 2A: $t\,(11) = 2.046, p = 0.025$; and *4A*: $t\,(13) = 2.783, p = 0.016$). Infants in the *2Y 2A* group did not produce significantly more actions than infants in the *Baseline-NC* condition ($t\,(22)=1.52$, *n.s.*), and produced significantly fewer target actions than infants in the *2A* condition ($t\,(22)=2.78, p = 0.011$).

Consistent with previous research (Hayne *et al.*, 1997), these results demonstrate that 12-month-old infants are less successful at retrieving their memory in a deferred imitation task when they are tested with a stimulus that differs in form from the one presented during the demonstration session. The present study also demonstrated that generalisation at this age was not facilitated by an increase in the number of demonstrations, the temporal distribution of demonstrations, or by exposing infants to variability in the stimulus during the demonstration. Rather, the results indicate that a change in the shape of a central stimulus has a robust effect on memory in 12-month-old infants.

Importantly, although infants tested with a puppet of a different form did produce more actions than the *Baseline-NC* group, they produced significantly fewer actions than infants tested with the puppet seen during the demonstration session. Thus, the lack of facilitation observed was not attributable to a ceiling effect. Intriguingly, the one manipulation that did have an effect (giving variability training with two very different stimuli) actually abolished generalisation, rather than facilitating it. This indicates that the level of generalisation exhibited by the remaining form-change groups cannot be attributed to a floor effect. Rather, the majority of 12-month-old infants in this study showed a consistent, but low level, of generalisation across a change in form.

5.3. Experiment 6: The effect of extra experience in the test location

5.3.1. Experiment 6a: The effect of extra experience in the test location on generalisation

Although previous imitation research with 6- and 24-month-old infants has demonstrated that it is possible to facilitate generalisation (e.g., Barr *et al.*, 2003; Campanella & Rovee-Collier, 2005; Herbert & Hayne, 2000b), no facilitatory effects were obtained in Experiment 5. However, in four of the form change conditions in Experiment 5 there were consistent, but low, levels of generalisation. In contrast, 12-

month-old infants tested with the same stimuli and after the same delay in Hayne *et al.* (1997) showed no evidence of generalisation. Identifying the crucial difference between the present results and those of Hayne *et al.* (1997) may provide further insight into the process controlling generalisation in infancy.

Although the two studies were identical in terms of stimulus and delay interval, it is possible that variation in the locations in which the experimental phases were conducted contributed to the differing results. In Experiment 5, the demonstration and test phases were conducted in a distinctive experimental room, whereas the initial greeting phase and the retention interval were spent in a reception room. This changing location design is in contrast to the experience of infants in Hayne *et al.* (1997), in which the entire session occurred in the same location, a room in the infant's home. Thus, whereas in Experiment 5 the location of testing was uniquely associated with the deferred imitation paradigm, in Hayne *et al.* (1997) it had previously been associated with a range of other experiences. The purpose of Experiment 6a was to examine the effect of a unique learning/test location on generalisation, in comparison with conditions in which the location has been experienced prior to learning, or continues to be experienced between learning and retrieval. If a unique learning/test location has an important facilitatory influence on generalisation, extra experience in the testing location may negatively impact on generalisation.

5.3.1.1. Participants

Forty-eight 12-month-old infants (24 female) were recruited as in Experiment 5. Testing was discontinued on additional infants who were excessively fussy or cried during testing ($n = 3$), who failed to interact during the warm-up phase ($n = 5$), or due to parental interference ($n = 2$).

5.3.1.2. Apparatus

The apparatus were identical to Experiment 5.

5.3.1.3. Procedure

Infants were randomly assigned to one of 3 demonstration conditions ($n = 36$; 18 females, 18 males) or a *Baseline* condition ($n = 12$). There were six male and six female infants in each group. The general procedural details were identical to Experiment 5 with the exception that the location of the initial greeting and the retention interval was manipulated across groups (see Table 5.3). Infants in the *Leave Room* condition only experienced the puppet task in the experimental room (in an identical procedure to the *2A* group in Experiment 5). Infants in both the *Start in Room* and *Stay in Room* groups spent an extra 10 minutes in the testing location prior to the test session. Other than the location in which those periods were spent, all other activities and procedures were identical across conditions.

Group	*Experimental Phase*			
	Greeting (10 minutes)	**Demonstration**	**Retention Interval (10 minutes)**	**Test**
Baseline	Reception	Experimental	Reception	Experimental
Leave Room	Reception	Experimental	Reception	Experimental
Start in Room	Experimental	Experimental	Reception	Experimental
Stay in Room	Reception	Experimental	Experimental	Experimental

Table 5.3. The room experienced during each phase of Experiment 2 as a function of group assignment.

All infants interacted in a free-play greeting session with their parents and the experimenter for 10 minutes prior to the demonstration session. The demonstration session (which occurred in the experimental room) was identical to that used in the *2A* condition of Experiment 5. The *Baseline-FC* demonstration was identical to that used for the *Baseline-NC* group in Experiment 5.

At the end of the demonstration, infants in the *Leave Room*, the *Baseline-FC* and *Start in Room* groups, their caregiver, and the experimenter left the experimental room and returned to the reception room for the 10-minute retention interval. Infants in the *Stay in Room* group remained in the experimental room throughout the retention interval. In all conditions, infants were free to explore the room during the retention interval, and the target stimulus was removed from sight. The same children's toys were available for the infant to play with in both locations (puzzle, blocks, and pop-up toy).

The test session occurred in the experimental room for all groups. Any additional toys were removed from the testing location and the infant was once again seated on the caregiver's lap in the experimental room. All infants, including infants in the *Baseline-FC* group, were tested with a stimulus that differed in form from the demonstration stimulus.

5.3.1.4. Results and Discussion

The data was coded and analysed as in Experiment 5. A Pearson product-moment correlation yielded an inter-observer reliability coefficient of 1.0.
Preliminary analyses confirmed that scores were not influenced by the gender of the infant, the particular stimulus used during the demonstration session, or the particular stimulus used during the test session, and so further analyses were collapsed across these variables. Table 5.4 shows the patterns of performance of individual infants.

	Number of actions	*0*	*1*	*2*	*3*
Form Change (Experiment 6a)	*Baseline-FC*	10	2	0	0
	Leave Room	3	5	4	0
	Start in Room	8	1	3	0
	Stay in Room	9	1	2	0
No Change (Experiment 6b)	*Leave Room*	5	2	2	3
	Stay in Room	4	3	4	1

Table 5.4. The number of 12-month-old infants producing 0, 1, 2 or 3 target actions in each condition in Experiment 6a and 6b.
A score of 1 indicates that the infant removed the mitten, a score of 2 indicates they removed the mitten and either shook or replaced/attempted to replace the mitten, and a score of 3 indicates they performed all three actions.

To assess whether there were any differences in imitation as a function of experience in the test location, the data from the demonstration groups were subjected to a one-way between-subjects ANOVA with group as the between-subjects variable. There was no significant main effect of group (F (2,35)=2.095, *n.s.*).

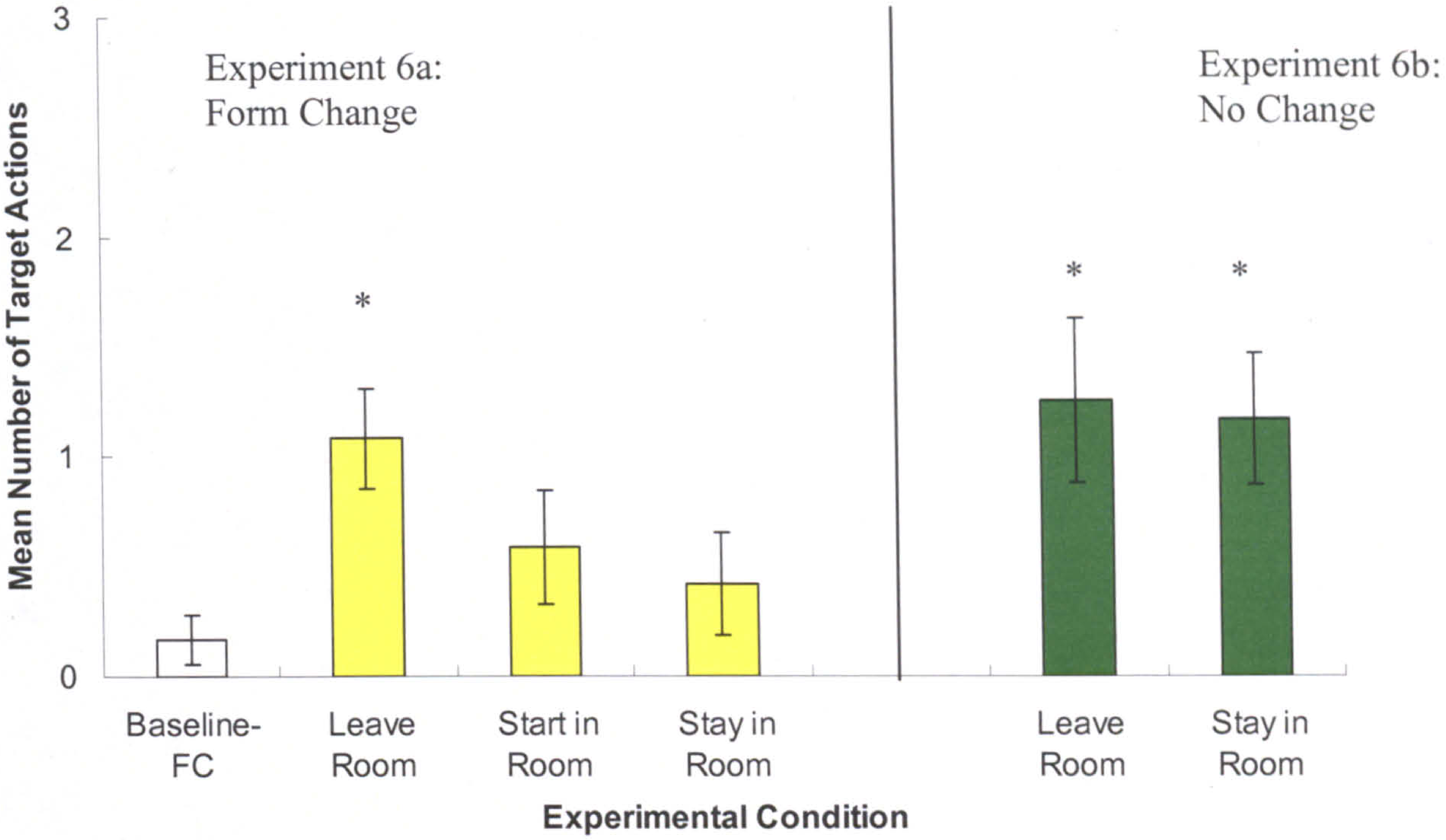

Figure 5.3. The effect of extra experience in the testing location on cued recall in 12-month-old infants.
The mean number of target actions (+/- 1 Standard Error) produced by each group of infants (n = 12 in each group) as a function of experience with the testing location, and the stimulus used during the test session. An asterisk indicates that the group imitation score is significantly greater than that of the *Baseline* group ($p<0.05$).

To assess whether any of the test groups showed retention of the target actions, the mean number of target actions produced by each demonstration group was compared to the *Baseline* group with two-tailed independent samples t-tests (Figure 5.3). These analyses indicated that infants in the *Leave Room* group performed significantly more target actions than infants in the *Baseline* group (t (22) = 3.60, p = 0.002). However, both groups of infants who received extra time in the experimental room did not produce significantly more target actions than infants in the *Baseline* group (*Start in Room*: t (22)=1.47, *n.s.*; *Stay in Room*: t(22) = 0.98, *n.s.*). Thus, when infants received an extra ten minutes in the experimental room they did not show evidence of generalisation, regardless of whether that exposure occurred before the demonstration session, or during the retention interval. In other words, generalisation was only observed when the only event infants experienced in the testing room was the deferred imitation paradigm.

Is this effect specific to generalisation, or does the degree of experience infants have in the test location also have an impact on imitation more generally? Answering this question may reveal whether the same factors control memory retrieval with the same stimulus, and memory retrieval with an altered stimulus, something that has not been directly explored thus far with infants.

5.3.2. Experiment 6b: The effect of extra experience in the test location on exact imitation

To examine whether the facilitative effect of a unique learning and test location was specific to generalisation, two additional groups of infants were tested in the imitation procedure, with no change in the stimulus at test. One group of infants left the testing location (a *Leave Room* group as in Experiment 6a) and one group remained in the test location during the retention interval (a *Stay in Room* group as in Experiment 6a). No groups received pre-exposure to the experimental room. The *Stay in Room* manipulation was chosen over the *Start in Room* manipulation because the former had the greater effect on generalisation in Experiment 6a.

5.3.2.1. Participants

Twenty-four 12-month-old infants (12 female) were recruited as in Experiment 5. Testing was discontinued on additional infants who were excessively fussy or cried during testing ($n = 3$). Infants were randomly assigned to the two demonstration groups. There were six male and six female infants in each group. The performance of these groups was compared to the performance of infants in the *Baseline-NC* condition of Experiment 5, as these infants were also tested with the same puppet they saw during the demonstration session.

5.3.2.2. Apparatus

The apparatus were identical to Experiment 5.

5.3.2.3. Procedure

The general procedural details were identical to those given in Experiment 6a for the *Leave Room* and *Stay in Room* groups. The only procedural difference was that the stimuli used in the demonstration and test sessions were identical in Experiment 6b, whereas in Experiment 6a they differed in form.

5.3.2.4. Results

The data was coded and analysed as in Experiment 6a. A Pearson product-moment correlation yielded an inter-observer reliability coefficient of 0.96. For comparison, the imitation scores of the two demonstration groups were compared to the score of the *Baseline* group in Experiment 5, who had also been tested with the same stimulus at demonstration and test.

Preliminary analyses confirmed that scores were not influenced by the gender of the infant, the particular stimulus used during the demonstration session, or the particular stimulus used during the test session (all $p > 0.05$), and so further analyses were collapsed across these variables. The mean number of actions produced by each group of infants is shown in Figure 5.3. Table 5.4 shows the patterns of performance of individual infants making up the mean scores.

Two-tailed independent-samples t-tests revealed that infants in both the *Leave Room* and *Stay in Room* groups performed significantly more target actions than infants in the *Baseline-NC* condition from Experiment 5 (*Leave Room*: t (12) = 3.062, $p = 0.01$; *Stay in Room*: t (13) = 3.509, $p = 0.004$). A further independent-samples t-test confirmed that there was no significant difference between the average number of target actions produced by infants in the two demonstration conditions (t (19) = 0.621, *n.s.*).

The location in which the retention interval was spent did not affect memory for the specific target actions when infants were tested with the demonstration puppet. The facilitative effect of a change of location during the retention interval was thus limited to generalisation.

5.4. General Discussion

The present study explored whether generalisation across a change in stimulus form could be facilitated in a purely observational learning paradigm for 12-month-old infants. Increasing the amount of training, distributing the training, or providing variability training had no facilitative effect on generalisation. Thus, 12-month-old infants' capacity for generalisation was remarkably robust to variations during the encoding session, despite the fact that performance was not constrained by ceiling effects, and in other paradigms generalisation is more readily facilitated when infants are already performing above-baseline (Hayne *et al.*, 2003; Herbert & Hayne, 2000). In contrast, the experience infants had with the testing location did affect generalisation, while having no effect on exact imitation (imitation with the demonstration stimulus). The provision of a unique location for encoding and retrieval likely accounts for the consistent, but low, levels of generalisation observed in Experiment 5 that had not been previously observed (Hayne *et al.*, 1997).

5.4.1. Variations in the encoding session had little impact on generalisation

On the surface, it is surprising that the variations in encoding employed in Experiment 5 had such little impact on generalisation. The various experiences provided for infants were based on procedures that have previously facilitated retention in imitation tasks, or facilitated generalisation in operant conditioning paradigms. For example, doubling the number of demonstrations in a deferred imitation task allows 6-month-old infants to remember the actions for longer (Barr *et al.*, 1996), presumably because these events have been more effectively encoded in memory. However, doubling the number of demonstrations for 12-month-old infants did not affect generalisation in the present study. Six- and 12-month-old infants may benefit from different types of experience (e.g., Learmonth *et al.*, 2004). Alternatively, it is possible that experiences that enhance performance on one type of imitation measure (e.g., exact imitation) are different from the experiences which might enhance performance on another type of memory measure (e.g., generalisation). For example, the results from Experiment 6a and 6b indicate that exposure to the learning/test context affects generalisation without impacting on exact imitation. Although these possibilities require further studies in order to be fully evaluated, the present study provides no evidence to suggest that allowing 12-month-old infants to repeatedly watch an event improves their ability to retrieve memory for that event when presented with an altered cue.

In the present study, variability training had no facilitative impact on generalisation, whereas in operant conditioning paradigms variability training is highly effective (Hayne, Greco-Vigorito, & Rovee-Collier, 1993; Rovee-Collier, Greco-Vigorito & Hayne, 1993). To date, there have been no studies showing that variability training is effective in the deferred imitation paradigm. Variability training may in part be successful in operant conditioning paradigms because the infant is given the opportunity to interact with each exemplar. Learning through physical practice may increase the number of retrieval cues available to the infant, and so the effects of varying the encoding session may be magnified by the inclusion of physical experience at each stage. Alternatively, self-generated information may be less dependent on specific stimulus features than information presented by others. With adults, for example, memory for self-generated stimuli is less affected by a change in stimulus colour than is memory for stimuli presented to the participant (Mulligan *et al.*, 2006). When infants are allowed to learn through practice, they are generating part of the information to be learned, and this may render recall of that information less dependent on specific features of the stimuli used. Whether variability training can be effective in a deferred imitation task when learning occurs through observation alone awaits further research.

5.4.2. Negative effects of variability training

Intriguingly, when the two training stimuli differed considerably in colour and form (the 2Y*2A* condition), variability training actually decreased the otherwise limited but robust levels of generalisation expressed across groups. It is unlikely that seeing the demonstration with two very different puppets could have produced an interference effect, because interference is typically greater when stimuli are more similar (Medin, Reynolds & Parkinson, 1980; Rossi-George & Rovee-Collier, 1999; Spear, 1978). Thus, if anything, greater interference would be expected in the *2A'2A* condition than in the 2Y*2A* condition. A more plausible possibility is that due to primacy effects, infants remembered the first two demonstrations they saw better than the second two demonstrations. Indeed, infants show strong primacy effects in both the VPC procedure and the mobile task (Cornell & Bergstrom, 1983; Gulya, Rovee-Collier & Merriman, 1996). In the 2Y*2A* condition in the present study, the magnitude of the perceptual difference between the first puppet and the test puppet was much greater than in the other conditions. Thus, if infants only remembered the first two demonstrations, they would find it more difficult to apply what they had seen to the test puppet in the 2Y*2A* condition than in the other conditions. Exploring the effect of varying the order of the stimuli seen in variability training procedures would address this possibility.

5.4.3. The effect of extra experience in the learning and testing location

Some evidence of facilitation of generalisation was identified in this study: that mediated by the location of the deferred imitation task. Experiment 6a revealed that although 12-month-old infants have a limited ability to generalise across a form change when the deferred imitation paradigm is the only event experienced in a particular location, this ability is abolished when they have a brief period of extra experience in this location. It is unlikely that effects can be attributed to behavioural inhibition in a novel environment, as this would predict poorer performance when exposure to the environment was limited, rather than the facilitatory effect seen in the present study. Thus, providing a unique environment for learning and retrieval appears to produce a limited facilitatory influence on generalisation.

Associative learning mechanisms may underlie the facilitative effect of a unique learning and testing context on generalisation. Pre-exposure to two puppets allows infants to associate them, such that during the test session the presence of one puppet can cue retrieval of the other, and hence memory for the target actions (Barr *et al.*, 2001; Campanella & Rovee-Collier, 2005). Infants can also form and use associations between environmental features and central stimuli (Cuevas *et al.*, 2007). In the present study, infants may have associated the distinctive test room to the puppet and actions during the learning session. The demonstration stimulus may have provided a sufficiently strong retrieval cue to memory for the target actions in the No Change groups, and so support from environmental features may not have been required. Indeed, 12-month-old infants can generalise across a change from their home to the laboratory over a 24-hour delay

(Hayne *et àl.*, 2000), indicating that when the stimulus used during the demonstration and test sessions is the same, environment details exert little influence on retrieval. However, a stimulus of a different form may not provide a strong enough retrieval cue. Retrieval cues from the location of testing may then become useful in cuing memory for the target actions.

The present data imply that the degree of influence location cues can exert over generalisation in 12-month-old infants depends on the experience infants have within the learning and testing location. When infants played with a range of other toys for 10 minutes in the test location, generalisation was no longer seen. Thus, generalisation only occurred when the puppet task was the only experience infants had in the testing location. The cue-overload hypothesis (Earhard, 1967; Watkins, 1979; Watkins & Watkins, 1975) states that as more target items are associated with a particular cue, it becomes less likely that the cue will evoke any of the target items. The cue overload hypothesis fits well with the present results if it is assumed that the more stimuli the infant experienced in a particular location, the less likely that retrieval cues from that location could cue retrieval of any particular stimulus. Thus, the location could only cue memory for the target actions when the location was uniquely linked to the puppet task.

5.4.4. The changing role of the environment in memory retrieval

Between the ages of 6- and 12-months, infants become less reliant on details of the social and physical environment to cue memory retrieval (Chapters 3 and 4). However, details of the central stimulus remain important across this age range, and by 12-months appear to exert a degree of priority in memory retrieval (Hayne *et al.*, 2000). In the present study, when the test stimulus was identical to the demonstration stimulus, memory was unaffected by the strength of environmental cues from the testing location (Experiment 6b). Environmental cues only had an impact when the central stimulus provided insufficient cues to memory retrieval (Experiment 6a). In contrast, the strength of the cues provided by the stimulus had an impact on retrieval both when environmental cues were strongly predictive of the target actions (groups *2A* and *2A-NC* in Experiment 5), and when they were only weakly predictive (*Stay in Room FC* and *NC* in Experiment 6). Twelve-month-old infants may be more reliant on environmental information when central stimuli are absent or altered, implying that they have encoded both the stimulus and its environment in their memory representations, and that these elements have asymmetrical effects on retrieval. Whether age-related decreases in the effect of a change of environment on memory retrieval are driven by age-related changes in the balance of the environment and stimulus in the memory trace is an important topic for further research.

Chapter 6: Investigating the effect of a context change on the neural correlates of recollection and familiarity

6.1. Introduction

Over the first year of life, contextual changes have a progressively smaller impact on memory retrieval. Whereas at 6-months memory retrieval is precluded by a change of context in a variety of paradigms (e.g., Hayne *et al.*, 2000; Learmonth *et al.*, 2004, 2005; Chapter 2), by 12-months, contextual details influence but do not preclude retrieval in both cued recall (Hayne *et al.*, 2000; Experiments 1,3 and 4) and recognition (Robinson & Pascalis, 2004; Experiment 2) tasks. To begin to understand how contextual details come to play a decreasing role in memory retrieval across the first year of life, it is crucial to explore the processes underlying contextual influences on memory retrieval.

Dissociations between different memory processes have been characterised in most detail in the mature brain (reviewed by Aggleton & Brown, 1999; Gabrieli, 1998; Squire, 2004; Yonelinas, 2002). As different memory processes are currently less specified in infant memory, adult research has previously proved a useful guide to hypotheses about the development of memory mechanisms in infancy (e.g., Adlam *et al.*, 2005; Manns *et al.*, 2000; McDonough *et al.*, 1995). For example, Hayne (2004) has argued that performance on a deferred imitation task in infancy requires 'declarative-like' memory partly on the basis that adult amnesic patients who may lack declarative memory fail a deferred imitation task (McDonough *et al.*, 1995). Studies with adults can thus provide some insight into changing memory mechanisms in infancy. However, the fact that infants and adults may accomplish the same task using different cognitive processes means that research with adults can only shape hypotheses that should be directly tested with infants.

The aim of the present Chapter was to explore the memory processes that are influenced by a contextual change with adults. To increase the potential applicability of the study to infant memory, the study was designed such that the major aspects of the chosen methodology have been previously used in infant research. The study centered on the widely accepted hypothesis that two processes underlie performance in recognition and cued recall tasks: familiarity and recollection.

6.1.1. Dual-processes in recognition memory: familiarity and recollection

Although not universally accepted (e.g., Donaldson, 1996; Dunn, 2004; Heathcote, Raymond & Dunn, 2006), "it is probably fair to say that the majority of contemporary researchers adhere to some kind of dual-process model" of recognition memory (Rugg & Curran, 2007, p 251). Dual-process theories of recognition memory propose that recognising an item can either rely on a feeling of *familiarity* for that item, or a specific *recollection* of the precise occasion upon which the item was previously presented, although there are many different theories concerning the exact nature of, and relationship between, these processes (reviewed by Yonelinas, 2002). Familiarity is generally thought to be a signal-detection based process that acts on individual stimuli, or pairs of stimuli that can be 'unitised', or fused (Jaeger, Mecklinger & Kipp, 2006; Opitz & Cornell, 2006; Yonelinas *et al.*, 1999). In contrast, recollection is thought to be a threshold-based binary decision about whether an item has previously been presented, made on the basis of whether any details surrounding the previous presentation of the item can be retrieved (e.g., Donaldson & Rugg, 1998; Norman & O'Reilly, 2003; Yonelinas, 1994). Recollection is thought to be hippocampally-dependent, whereas familiarity relies more critically on extra-hippocampal structures (reviewed by Aggleton & Brown, 1999; Eichenbaum *et al.*, 2007; Norman & O'Reilly, 2003), although a range of other brain areas, such as regions of the frontal and parietal cortices, are also involved in both processes (reviewed by Rugg & Yonelinas, 2003; Wagner, Shannon, Kahn & Buckner, 2005).

As familiarity and recollection have been linked to different cognitive and neural mechanisms, the dissociation provides a rich theoretical framework within which to examine context-shift effects. Dual-process models of memory have yet to be applied to infant memory, but exploring the influence of a context change on familiarity and recollection in adulthood may provide a deeper understanding of the mechanisms underlying context-shift effects, which could then provide further insight into infant memory development. One method that can be used to distinguish between recollection and familiarity in adulthood (reviewed by Curran, Tepe & Piatt, 2006; Friedman & Johnson, 2000; Rugg & Yonelinas, 2003) and is suitable for infants (reviewed by Nelson

& Monk, 2001) is the use of Event-Related Potentials (ERPs) measured through an electroencephalogram (EEG). The rationale of EEG measurements is briefly reviewed in the next section.

6.1.2. EEG-recorded ERPs

EEG is a recording of brain activity with high temporal resolution (for details see Allison, 1984; Niedermeyer & Lopes da Silva, 2005; Nunez, 2002). EEG data is generated by recording from a series of electrodes positioned at particular locations on the scalp (a montage). The resulting signal reflects the electrical activity of large numbers of neurons in the brain. These neurons are typically parallel-oriented pyramidal cells from the cortex, and the hippocampus (Allison, 1984). Measuring EEG is efficient and non-invasive, and unlike fMRI does not require encapsulation in a confined space. EEG is thus potentially suitable for all age groups.

One way to use EEG to study cognition is to examine Event-Related Potentials (ERPs). ERPs are voltage changes induced in the brain in response to a variety of sensory, cognitive and motor processes (for methodological reviews see Fabiani, Gratton & Coles, 2000; Rugg & Coles, 1995). ERPs are generated by averaging the EEG-recorded neural activity provoked by a stimulus that has been repeatedly presented on many trials. As background neural activity that is not related to the stimulus is assumed to vary independently of the test trials throughout the test session, by averaging across a number of trials non-stimulus-related activity is cancelled out. The remaining signal consists of a series of positive and negative deflections distributed over time that are specifically related to the stimulus presented on each trial.

Significant deflections in the ERP waveform are called 'components' when they are thought to reflect an interesting cognitive process. Components are typically labelled by the latency of the peak of the deflection after stimulus onset, and the area of the scalp over which the deflection is most prominent (see Figure 6.1). ERP components can be analysed in terms of the mean amplitude of the waveform across a particular time window, the amplitude of a particular peak, or the latency of that peak. ERP components are associated with particular cognitive processes through examining whether their mean amplitude, peak amplitude and/or latency are affected by experimental conditions that alter the cognitive process in question. For example, a component that is different in amplitude or latency to novel and familiar stimuli may be associated with memory retrieval.

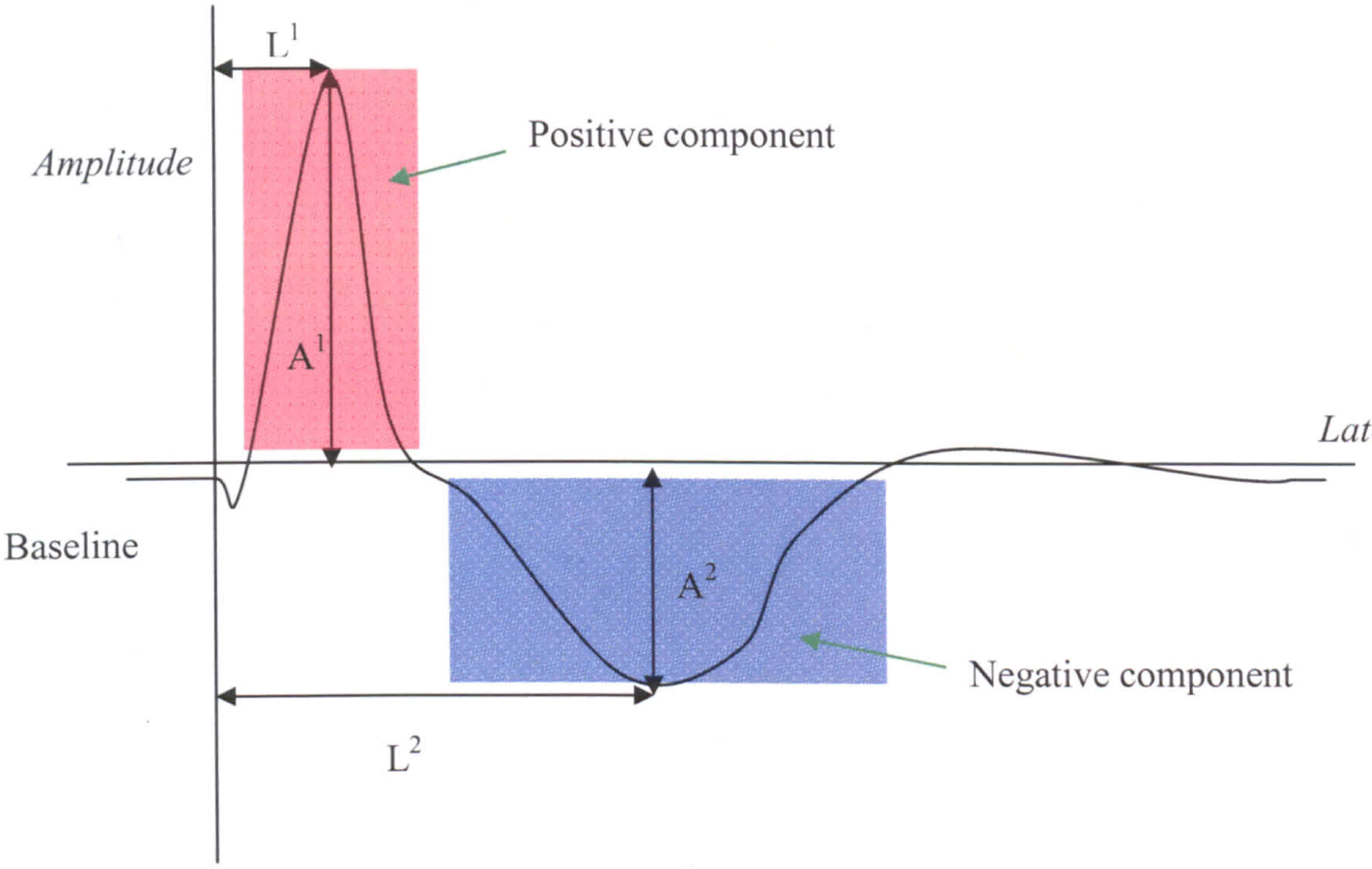

Figure 6.1. Stylised version of an ERP waveform.
L^1 and A^1 represent the peak latency and amplitude of the positive component respectively, and L^2 and A^2 represent the peak latency and amplitude of the negative component respectively. Mean amplitude is calculated by averaging the amplitude of the waveform at each recorded time-point across the selected time-window (shown in red and blue shading). In the present study, the sampling rate was 250Hz, thus providing an amplitude reading every 4ms. Throughout this Chapter the waveforms will be presented with positive amplitude above the x-axis, and negative amplitude below.

6.1.3. Using ERPs to distinguish recollection and familiarity in adulthood

In adulthood, ERPs have been widely used to distinguish between recollection and familiarity. With a few exceptions (e.g., Mackenzie & Donaldson, 2006;Yovel & Paller, 2004, Voss & Paller, 2007; see Section 6.5.4), recollection has been associated with a positive-going deflection (positivity) between 500 and 800ms after stimulus onset that is maximal over parietal electrodes (the Late Positive Complex, or LPC[8]). Familiarity has been associated with a negative-going deflection (negativity) around 300 to 500 ms after stimulus onset that is maximal over frontal-central electrodes (the Frontal Negativity 400, or FN400[9]) (e.g., Curran, 2000; Curran & Friedman, 2004; Duzel, Yonelinas, Mangun, Heinze & Tulving, 1997; Rugg *et al.*, 1998; Wolk *et al.*, 2006; reviewed by Curran *et al.*, 2006; Friedman & Johnson, 2000; Rugg & Curran, 2007). The terms 'FN400' and 'LPC' refer to the components themselves, whereas the terms 'FN400 old/new effect' and 'LPC old/new effect' refer to the difference between the amplitude of the FN400 and LPC components to 'old' and 'new' stimuli (defined within the experiment). Thus, the FN400 old/new effect is thought to occur when stimuli are recognised through a feeling of familiarity, and the LPC old/new effect is thought to occur when stimuli are recognised through recollection (see Figure 6.2 for a typical example).

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[8] ERP components are often labelled differently in different studies. Although Olichney *et al* (2000) labelled this component the LPC, other researchers have labelled it the P300 old/new difference (Johnson, 1995), the late ERP old/new effect (Rugg, 1995), or the P600 old/new effect (Curran, 1999). In the present Chapter, the term 'LPC' will be used throughout for clarity.

[9] The FN400 has also been termed the mid-frontal (Tsivilis *et al.*, 2001), medial frontal (Friedman & Johnson, 2000), or early frontal old/new effect (Mecklinger, 2000). In the present Chapter, the term 'FN400' will be used throughout for clarity.

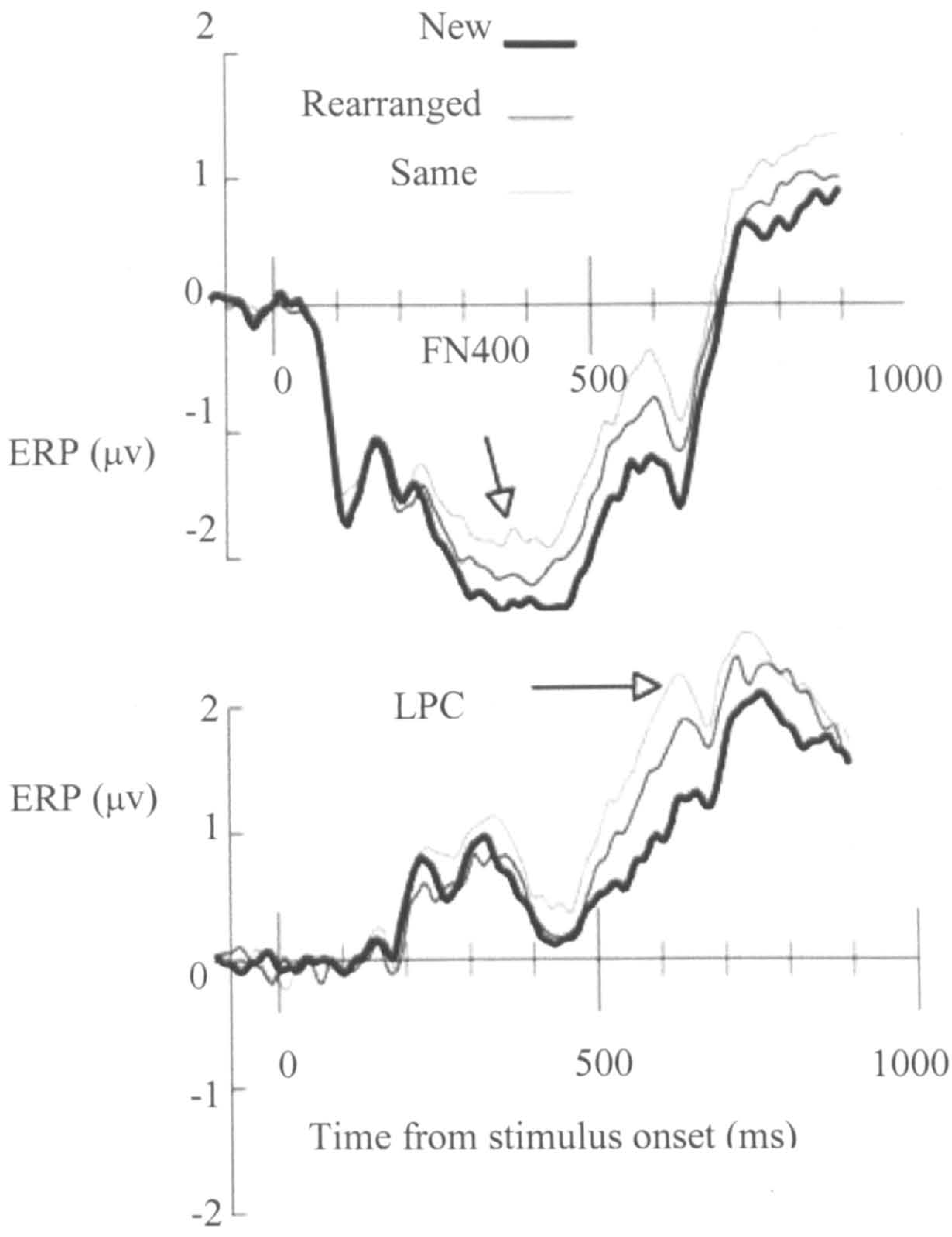

Figure 6.2. An example of the FN400 (top) and LPC (bottom) measured on a 128-electrode Geodesic sensor net.
The FN400 was measured from frontal groups of electrodes, and the LPC was measured from parietal groups of electrodes. In the study (Piatt *et al*., unpublished), participants saw a sequence of objects on different backgrounds. ERPs were calculated from test trials on which participants correctly rejected new objects (New), or correctly identified as 'old' objects that had been previously studied (Same and Rearranged). The old objects were either presented on their original backgrounds (Same), or on a different background that had been studied during the learning session (Rearranged). The FN400 old/new effect is reflected in the more negative-going deflection for new than old stimuli in the top waveform, and the LPC old/new effect is reflected in the more positive-going deflection for old than new stimuli in the bottom waveform. Adapted from Curran *et al*., 2006.

Several lines of evidence link the FN400 and LPC to familiarity and recollection respectively. For example, in the 'remember/know procedure' (Tulving, 1985), participants are asked to say whether they 'remember' each familiar stimulus (thought to reflect recollection), or whether they 'know' they have seen it before (though to reflect familiarity). The mean amplitude of the LPC is greater for words that participants judge as 'remembered' than those that they judge are 'known' (e.g., Duzel *et al.*, 1997), indicating that the LPC component is larger when conscious recollection occurs. Congruently, manipulations such as increased attention during encoding, or processing the meaning rather than the perceptual features of a stimulus, increase the proportion of 'remember' responses given, and also modulate the mean amplitude of the LPC but not the FN400 (Curran, 2004; Rugg *et al.*, 1998; Yonelinas, Kroll, Dobbins, Lazzara & Knight, 1998). In contrast, the FN400 varies with confidence judgements attached to 'known' stimuli, but does not differentiate high confidence 'known' stimuli from 'remembered' stimuli (Woodruff, Hayama & Rugg, 2006). This indicates that the FN400 varies with the strength of familiarity, but is insensitive to the presence of conscious recollection.

Other studies have examined the neural response to lures that are similar to studied stimuli. For example, a participant might study the word 'car', and then be presented with the studied stimulus and a similar lure ('cars') during the test session. Similar lures should produce a strong familiarity signal because they are very similar to the studied stimuli, but a weak recollection signal because they are not the precise items that were seen during learning (Hintzmann & Curran, 1994). Thus, the LPC should differ in magnitude to studied stimuli and similar lures, whereas the FN400 should not differentiate between these stimulus types. This pattern of findings has been obtained in several EEG studies with both verbal and pictorial stimuli, in which participants were asked to distinguish between studied items and similar lures[10] (Curran & Cleary, 2003; Curran, 2000; Nessler & Mecklinger, 2003; Nessler, Mecklinger & Penney, 2001).

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[10] Notably, in studies where participants are not asked to distinguish between similar items and studied lures (called 'inclusion' conditions), the opposite of this pattern is typically seen (see Section 6.1.4). Thus, a change in the features of a target stimulus may be processed differently when those features are part of the to-be-remembered information, than when they form part of the task context.

A further important difference between recollection and familiarity is that recollection is thought to involve retrieval of details about the previous presentation of a stimulus, whereas familiarity is not. A similar distinction can be made between the LPC and the FN400 (Villberg, Moosavi & Rugg, 2006; Wilding, Doyle & Rugg, 1995; Wilding & Rugg, 1996; Woodruff *et al.*, 2006). For example, the LPC is modulated by the recollection of specific details about target items, such as study modality (e.g., Wilding, Doyle & Rugg, 1995) or speaker's voice (Wilding & Rugg, 1996). Indeed, the magnitude of the LPC is correlated with the amount of information recollected about an item (Villberg *et al.*, 2006). In contrast, the FN400 is not typically modulated by the retrieval of contextual details (Woodruff *et al.*, 2006). This suggests that the LPC may reflect recognition accomplished by the recollection of a range of details about the previous presentation of a stimulus, whereas the FN400 reflects recognition accomplished through the familiarity of the items present during the test session.

Finally, the FN400 and LPC appear to be produced by similar brain structures to those that have been associated with recollection and familiarity through other measures, such as fMRI (reviewed by Rugg & Curran, 2007; Skinner & Fernandes, 2007; Rugg & Yonelinas, 2003). In fMRI studies, recollection has been associated with increased activity in the left inferior lateral parietal cortex (Eldridge, Knowlton, Furmanski, Bookheimer & Engel, 2000; Henson, Rugg, Shallice, Josephs & Dolan, 1999; Yonelinas, Otten, Shaw & Rugg, 2005), and has also been linked to increased activity in the hippocampus (Cansino *et al.*, 2002; Dobbins, Rice, Wagner & Schacter, 2003; Eldridge *et al.*, 2000). Similarly, the LPC is thought to be generated by areas of the parietal cortex, in association with the hippocampus (Allan, Wilding & Rugg, 1998; Duzel, Vargha-Khadem, Heinze, & Mishkin., 2001; Johnson, 1995a; Rugg, Otten & Henson, 2002; Wagner *et al.*, 2005). Familiarity has been associated with maximal activity on an fMRI measure in the left inferior and anterior prefrontal cortices (Yonelinas *et al.*, 2005), concurring well with the putative left frontal generators of the FN400 (Woodruff *et al.*, 2006). Thus, there is converging evidence that the FN400 and LPC are associated with different neural processes, are produced by different brain regions, and that they reflect familiarity and recollection respectively.

6.1.4. The influence of a contextual change on the FN400 and LPC

Since there is good evidence that the FN400 and LPC can be used as electrophysiological markers for familiarity and recollection, exploring the effect of a context-change on these two components may illuminate the processes underlying contextual influences on memory retrieval. When reviewing previous studies in this area, it is important to distinguish between studies that have explored different types of contextual information (Ecker *et al.*, 2007b). Behaviourally, changes of intrinsic context have a greater effect on familiarity than recollection (reviewed by Yonelinas, 2002), whereas changes of local extrinsic context commonly have a greater effect on recollection than familiarity (Macken, 2002; though see McKenzie & Tiberghien, 2004).

Several studies have explored the effect of a change of intrinsic context on the magnitude of the FN400 and LPC, using the orientation of a picture, the colour of an object or the plurality of a word as intrinsic contextual attributes (e.g., Curran, 2000; Curran & Cleary, 2003; Curran & Dien, 2003; Groh-Bordin *et al.*, 2005; Schloerscheidt & Rugg, 2004). In these studies, similar LPC old/new effects for both similar lures and studied items were found, whereas the FN400 old/new effect was greater for studied items than for similar lures. However, Ecker *et al.* (2007b) found that both the FN400 and the LPC were sensitive to changes in the colour of a stimulus, and Guillaume and Tiberghien (2005) found that the LPC but not the FN400 was sensitive to changes in the expression of a face. Thus, whist the majority of studies show that a change of intrinsic context selectively influences familiarity, there is some evidence that it may also influence recollection in some circumstances.

Changes in local extrinsic context, such as the background upon which a stimulus is presented, have produced mixed effects on the LPC and FN400. For example, placing an object on a non-studied background at test attenuates the FN400, and may (Piatt, Curran, Collins & Woroch., unpublished; Tsivilis *et al.*, 2001) or may not (Ecker *et al.*, 2007b) have an effect on the LPC. Using a non-studied background during the test session may influence the magnitude of the FN400 component because the background captures attention and hence elicits its own familiarity signal, rather than because it influences the familiarity of the target object itself (Ecker *et al.*, 2007a). The familiarity of different backgrounds can be equated by comparing previously studied object-background pairings with objects placed on background that were previously studied in conjunction with a different object. Using this procedure, Tsivilis *et al* (2001) and Ecker *et al.* (2007b) found no difference in either the FN400 or LPC in response to rearrangements of studied object-background pairings. However, Guillaume and Tiberghien (2005) found an effect of rearranging face-background pairs on the LPC, and Piatt *et al.* (unpublished) found an effect of rearranging object-background pairs on both the LPC and the FN400. Overall, a change of local extrinsic context influences the neural correlates of familiarity and/or recollection under some circumstances.

The variance in the results of adult EEG studies employing different context changes, procedures and stimuli makes it difficult to determine the implications of existing research in this area for infant memory, because the types of contextual change that have typically been employed with infants are different to those employed with adults. In infant recognition memory studies, 'context' has either been defined as a background colour, simpler than the complex scenes typically used with adults (Coldren & Haaf, 1999; Haaf *et al.*, 1996; Robinson & Pascalis, 2004), or as the room in which stimuli are presented (Experiments 1 and 2; Bushnell *et al.*, 1984). To date, there have been no direct studies with adults of the effect of a change of global extrinsic context, such as a change of room, on the FN400 and LPC.

The aim of the present study was to explore the effect of a context-shift on the LPC and FN400 in adulthood, when 'context' was defined as a change of room, or a change of background colour. The study was designed to both provide greater insight into the processes underlying the influence of context on memory retrieval in the mature brain, and to be useful for interpreting the potential processes underlying context influences on memory retrieval in infancy. Furthermore, such studies may inform future infant studies of the neural correlates of contextual changes. After a procedure that produced reliable behavioural effects of a context change was identified (Experiment 7), EEG recordings and a yes/no recognition task were used to explore the influence of a change of room (Experiment 8) and a change of brightly coloured background (Experiment 9) on the behavioural and neural correlates of recognition memory in adulthood.

6.2. Experiment 7: The effect of a change of distal context on recognition memory in adults

Previous research indicates that the neural correlates of a context-shift effect may be more apparent when accuracy measures are also sensitive to a context change (Piatt *et al.*, unpublished; Tsivilis *et al.*, 2001). Furthermore, it is recommended that the neural correlates of cognitive processes are sought where those processes can also be identified behaviourally (Picton *et al.*, 2000). Thus, Experiment 7 examined whether the proposed procedure (detail are in Section 6.2.3 below) would produce a significant context-shift effect on a behavioural measure of recognition memory, when context was defined by the room in which testing was conducted.

It was important to choose a retention interval that would be likely to maximise the magnitude of context-shift effects. However, the way in which context-shift effects change over time is a matter of some debate (see Section 1.9.1). Only one study has directly explored changes in context-shift effects over time in a standard recognition memory paradigm with human adults (Bertsch & Sanders, 2005). In this study, adults showed a larger context-shift effect when memory was tested over a 2-day delay than when memory was tested immediately, or after a 7-day delay. Thus, it appears that testing over a 2-day delay might be most appropriate for detecting context-shift effects. However, Bertsch and Sanders (2005) used a change of background as the contextual manipulation. A change in global context, such as the room in which testing occurs, has the strongest effect on memory in rats immediately after learning (e.g., Land & Riccio, 1998, 1999). Given the present study uses a change of room, it may be that greater context-shift effects would be observed immediately. To identify the most appropriate retention interval for the EEG study, in Experiment 7 two groups of participants were tested; one immediately and one over a 2-day delay.

6.2.1. Participants

Participants were 24 undergraduate students (12 female, 12 male) at the University of Sheffield, who received course credit for participation. Participants ranged in age from 18 to 22 years, (mean = 19.1 years, SE. = 0.24). Participants of each gender were randomly assigned to one of the two between-subject retention-interval conditions, *Immediate* and *2-Day Delay* (n=12 per condition). The contextual manipulation was varied within-subjects, such that within each retention interval condition, each participant was tested for recognition of stimuli previously experienced in the context of testing (*Same Context* condition), and stimuli previously experienced in an alternate context (*Different Context* condition). All participants had normal or corrected-to-normal vision. The study was approved by the Department of Psychology ethics committee.

6.2.2. Apparatus and stimuli

Testing was conducted in two rooms in the Psychology Department at the University of Sheffield, which served as the two contexts. None of the participants was familiar with either of the rooms prior to the study. Room A had walls covered with dark material, and was dimly lit. This room was used as Room A in the experiments presented in Chapter 3, where a more detailed description can be found. Room B was long and narrow, with pale yellow walls, and was brightly lit by ceiling strip lights. A set of stairs led down into the room, where there were several large chairs and some covered testing equipment. This room was similar in lighting and temperature to Room B in the experiments presented in Chapter 3.

The stimuli were 288 colour photographs of common objects (such as fruit, homeware or toys) presented on a black background (see Figure 6.3 for examples). Objects were chosen because nonverbal stimuli have been used in all previous studies of context-shift effects with infants. Stimulus size varied, from approximately 4 x 4 cm to 8 x 8 cm. Stimuli were selected from the Hemera PhotoObjects collection (Encore Software) and were presented on a laptop computer using E-Prime software.

Figure 6.3. Examples of the stimuli used in Experiments 7 and 8.

The stimuli were pseudo-randomly assigned to two lists of 72 familiarisation stimuli, and one list of 144 foil stimuli. As the objects fell into categories (such as fruit, or homeware), care was taken that equal numbers of objects from each category were represented in the three lists. This measure was taken to remove the possibility that participants could identify a stimulus as familiar through its category membership. Two buffer stimuli were also prepared in the same way.

6.2.3. Procedure

For all participants, the experiment took place in two parts. In the first part, participants were asked to view the familiarisation stimuli. In the second part, participants were tested for their recognition of these stimuli with a yes/no recognition task[11]. For participants in the *Immediate* condition, the test session immediately followed the familiarisation session. In practice, this resulted in a retention interval of approximately 1 minute whilst the test session was set up on the laptop computer. For participants in the *2-Day Delay* condition, the familiarisation and test sessions were separated by a delay of approximately 2 days (range = 40 to 55 hours, M = 47.1, SD = 4.6). In both locations, participants were seated 0.5 m away from the screen, which was 34 cm by 22 cm.

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[11] Participants were not asked to make remember/know judgments, or source judgments, because these questions cannot be applied to infant populations. If these procedures have any influence on the ERP correlates of recognition memory, using them may reduce the comparability of the results to infant studies.

6.2.3.1. The familiarisation session

Half the participants viewed a set of 72 stimuli in Room A, before moving to Room B and viewing a second set of 72 stimuli. The stimuli were presented in a randomised order. The remaining participants experienced the contexts in the reverse order. Participants were told that their memory for these stimuli would subsequently be tested, so they should view each one carefully. Duration of viewing was self-directed, and on average participants viewed each familiarisation stimulus for 3.2 seconds (SE = 0.5). The familiarisation session lasted approximately 20 minutes.

6.2.3.2. The test session

Half the participants were tested in Room A, and half the participants were tested in Room B. Thus, half the familiar stimuli had previously been experienced in the testing context (*Same Context* condition), and half had been experienced in the alternate context (*Different Context* condition). The remaining stimuli were novel. The testing session was split into two halves, separated by a short break. The first stimulus presented in each half of the session was a buffer stimulus, and responses to this stimulus were not analysed. Stimuli were presented individually for 500 ms duration, in a random order. The presentation of each stimulus was preceded by a red fixation cross presented on a black background (1 second duration), and followed by a 1.2 second response period, signalled by a black screen.

Participants were given a button box to record their responses, and were asked to respond as quickly and as accurately as possible. Pressing the left/right button indicated that the picture was one that they had seen before, and pressing the right/left button indicated that the picture was new. The laterality of responses was counterbalanced amongst participants. The two buttons were marked with the words ‘old’ and ‘new’, so that participants could check their responses if necessary. The reaction time and accuracy of responses were recorded during the stimulus presentation, and the post-stimulus response period, giving participants a total of 1.7 seconds to respond. Stimulus presentation was independent of the participant’s behaviour, such that their speed of response to a stimulus did not influence the length of time that elapsed before the next fixation cross and stimulus were presented. This ensured there was no reward for responding excessively quickly. The entire testing session lasted approximately 20 minutes. After testing, participants were debriefed, and thanked for their participation.

6.2.4. Results and Discussion

There were no significant differences between mean accuracy or reaction time in any of the counterbalancing conditions, and no effects of gender, so data were collapsed across these variables (all $p<0.05$). Furthermore, there were no significant differences in reaction time across any of the conditions (presented in Table 6.1). This is not an unprecedented result, as Rutherford (2004) also found reaction time to be less sensitive than accuracy to environmental context change effects.

	Immediate		***2-Day Delay***	
	Familiar (Same Context)	Familiar (Different Context)	Familiar (Same Context)	Familiar (Different Context)
Hit Rate	0.84 (0.03)	0.86 (0.03)	0.74 (0.04)	0.67 (0.05)
D'	2.15 (0.25)	2.35 (0.26)	1.32(0.16)	1.08 (0.16)
Mean RT Correct (ms)	831.1 (97)	812.8 (97.8)	895.6 (62.6)	887.3 (77.5)
Mean RT Incorrect (ms)	844 (52.6)	838.6 (44.4)	837.1 (60.23)	822.8 (70)

Table 6.1. The effect of a change of room on recognition memory in adults.
Proportion of correct responses (Hit Rate), d' (Hit Rate-False Alarm Rate), and Reaction time of correct and incorrect responses for groups of adults (n = 12 in each group) tested either immediately, or after a 2-day delay. Standard errors are shown in parentheses.

Figure 6.4 shows the mean accuracy of participants in each condition (also shown numerically in Table 6.1). D' was also calculated (as z (Hit Rate) – z (False Alarm Rate)), as this measure is considered a valid measure of discrimination between the familiar and novel stimuli (Snodgrass & Corwen, 1988). Following Murnane and Phelps (1994), data were analysed using a Repeated Measures ANOVA on both hit rates and d'. A Repeated-Measures ANOVA on hit rates by Condition (*Same Context* or *Different*

Context), with Delay (*Immediate* or *2-Day*) as a Between-Subjects factor revealed no significant main effect of Condition (*F* (22)=1.2, *n.s.*), but there was a significant main effect of Delay (*F* (1,22) = 7.169, *p* = 0.014). Thus, performance was poorer when participants were tested after a 2-day delay than when tested immediately.

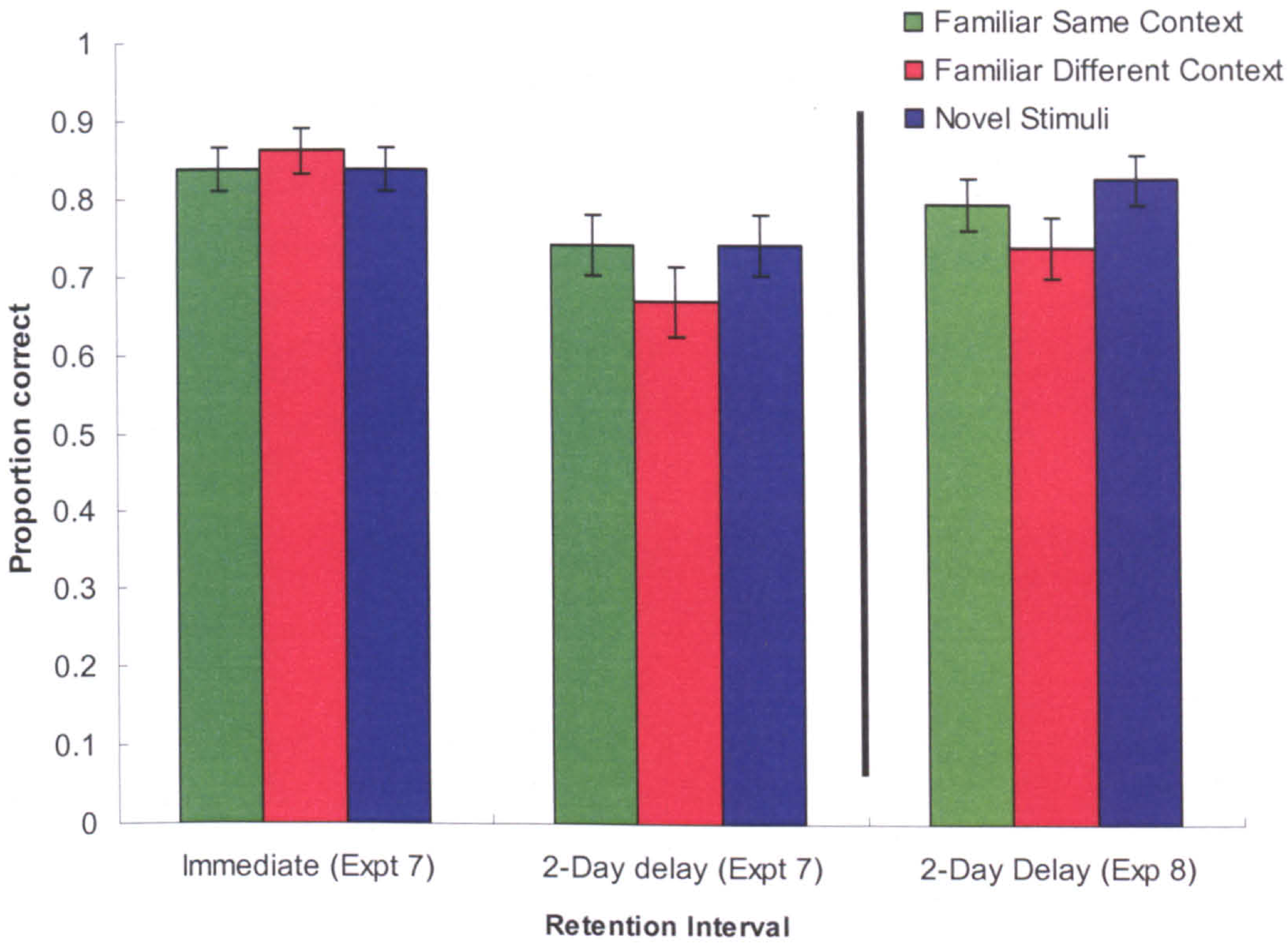

Figure 6.4. The mean accuracy of performance on the *Same Context*, *Different Context* and Novel stimuli in Experiments 7 and 8.
Stimulus type was manipulated within-subjects. Retention interval was manipulated between subjects (n = 12 in each group in Experiment 7, and n = 15 in Experiment 8).

Crucially, there was a significant interaction between Condition and Delay (*F*(22)=4.47, *p* = 0.046). Follow-up Bonferroni-corrected t-tests confirmed that adults performed more poorly in the *Different Context* condition than in the *Same Context* condition when testing occurred after a 2-day retention interval (*t* (11) = 2.297, *p* = 0.042), but performance was equivalent when the test immediately followed the familiarisation session (*t* (11) = 0.711, *n.s.*). It is unlikely that this can be attributed to a ceiling effect, as accuracy was around 80% in the *Immediate* condition. Context effects are sometimes seen when memory retrieval is poor. If this is the case in the present study, there should be a correlation between an individual's overall performance, and the difference between his or her performance in the *Same Context* and *Different Context* conditions. However, in the present data this correlation was not significant for either the *Immediate* or *2-Day Delay* conditions ($p < 0.05$).

The same pattern of results was found when d' scores were analysed with a Repeated Measures ANOVA with Delay (*Immediate* or *2-Day*) as the Between-Subjects variable and Condition (*Same Context* or *Different Context*) as the Within-Subject variable. There was a significant interaction between Delay and Condition ($F(22) = 8.22$, $p = 0.007$), and a significant main effect of Delay ($F(22) = 17.46, p < 0.001$). Follow-up Bonferroni-corrected t-tests confirmed that participants performed better in the *Same Context* condition than the *Different Context* condition over a 2-Day delay ($t\ (11) = 2.22$, p=0.049), but not when tested immediately ($t\ (11) = 1.17$, n.s).

Finally, the effect of delay on performance in each condition was analysed with two-tailed independent-samples t-tests on d' scores. Although there was no difference in d' score between the two delay conditions for the *Same Context* condition ($t\ (22) = 1.96$, *n.s.*), there was a significant difference in d' scores between the two delay conditions for the *Different Context* condition ($t\ (22) = 3.33, p$=0.03). Thus, participants only showed significant forgetting across the two-day retention interval in the *Different Context* condition.

In Experiment 7, a shift from one room to another influenced recognition memory for nonverbal stimuli in adult participants when memory was tested over a 2-day delay. These findings are congruent with previous research in this area that has utilised verbal stimuli with distinctive backgrounds (Bertsch & Sanders, 2005; see Smith & Vela, 2001 for meta-analysis). The present study confirmed that the chosen procedure would be suitable for assessing the effect of a context shift-effect on the FN400 and LPC in adulthood, providing memory was measured over a 2-day delay.

6.3. Experiment 8: The effect of a context-shift on the LPC and FN400

The aim of Experiment 8 was to explore the effect of a change of room on recollection and familiarity in adulthood, through measuring the LPC and FN400 with EEG. To this end, a second group of participants were tested in the same procedure that was used during Experiment 7. During the test session, participants' neural activity was recorded with an EEG, and the ERP components corresponding to the LPC and FN400 were analysed.

One potential drawback to assessing the FN400 after a 2-day retention interval is the rapidity with which it decays in some studies (Rugg, 1995; Rugg and Nagy, 1989; Van Petten, Kutas, Kluender, Mitchner & McIsaac, 1991). However, verbal stimuli were used in these procedures, and recognition accuracy tended to be relatively poor. In contrast, a study that used pictorial stimuli found a robust FN400 over a 24-hour retention interval when recognition accuracy was around 77% (Curran & Friedman, 2004). Since the present study used pictorial stimuli, and the accuracy level in the 2-day delay condition for the *Same Context* stimuli in Experiment 7 was 74%, the FN400 should be sufficiently robust in the present procedure to be detectable over a 2-day delay.

On the basis of previous research (e.g., Ecker *et al.*, 2007a,b; Tsivilis *et al.*, 2001), it is difficult to form a firm prediction as to whether the FN400 and/or LPC should be influenced by a change of room. However, behavioural studies indicate that extrinsic contextual changes may be more likely to influence recollection than familiarity (Macken, 2002). This leads to the tentative prediction that a change of room should have a greater influence on the LPC than the FN400 in the present study.

6.3.1. Participants

Participants were 31 undergraduate and graduate students at the University of Minnesota, MN. Undergraduate students received course credit for participation. All were right-handed with normal or corrected-to-normal vision, and participants were asked not to volunteer if they had any known neurological conditions (such as epilepsy). Data from sixteen participants were excluded (1 due to experimenter error, 4 did not complete both sessions, and 11 had fewer than 16 good trials per condition), resulting in a final sample size of n=15 (7 male). This 52% rejection rate is comparable with other published studies (e.g., 73%, Curran, 2004; 45%, Curran & Friedman, 2004; 33%,Woodruff *et al.*, 2006). The final sample ranged in age from 18 to 30 years (M = 24.5 years, SE = 1.1). Informed consent was obtained from each participant in line with the University of Minnesota Institutional Review Board guidelines, who provided ethical approval for the study.

6.3.2. Apparatus and stimuli

Testing was conducted in two rooms in the Psychology Department at the University of Minnesota, which served as the two contexts. None of the participants was familiar with either of the rooms prior to the study. Room C was a small, dark room with plain walls. The participant was seated in an area of the room that was marked on one side by a curtain, which divided the testing area from the stimulus presentation area. In Room C, the stimuli were presented on a desktop computer. Room D was a larger room that was brightly lit by natural light. The walls were painted white, and featured many notices and posters. In Room D, the stimuli were presented on a lap-top computer. The stimuli were the same as those used for Experiment 7.

6.3.3. Procedure

The experiment took place in two parts. In the first part, participants were allowed to view the familiarisation stimuli. In the second part, participants were tested for their recognition of these stimuli. The familiarisation and test sessions were separated by a delay of approximately 2 days (range: 44 to 56 hours, M = 49.0, SE = 1.0). Before the familiarisation session, participants were consented to the study, and completed a brief questionnaire to ascertain that they met the inclusion criteria for the study. These conditions were met by all participants.

6.3.3.1. The familiarisation session

The procedure of the familiarisation session was identical to that employed in Experiment 7, except that the two Contexts used were Rooms C and D. Duration of viewing was self-directed, and on average participants viewed each familiarisation stimulus for 3.4 seconds (SE = 0.67).

6.3.3.2. The test session

The behavioural procedure for the test session was the same as that for Experiment 7, except memory was tested in Rooms C or D. Furthermore, in addition to the instructions given in Experiment 7, participants in Experiment 8 were instructed to try to remain as still as possible during the test session, and to try to refrain from blinking when the stimuli were presented (a strategy recommended by Picton *et al.*, 2000).

6.3.3.3. ERP recording

During the test session, EEG was recorded continuously from a 128-channel Geodesic Sensory Net^{TM} v.2.0 (Tucker, 1993). The net was connected to an AC-coupled, 128-channel, high-input impedance amplifier (200M Ω, NetAmps TM, Electrical Geodesics Inc (EGI), Eugene OR). Gains and amplitude were calibrated before each participant was tested. Recording and analysis were carried out on an iMac using NetStation v 4.2.1, which interfaced with the E-Prime (v 2.0) presentation software used to administer the stimuli and record behavioural responses.

The size of net used for each test session was chosen according to the circumference of the participant's head, and this net was soaked in the electrolyte solution specified by the manufacturer (1L distilled water, 11g Potassium Chloride crystals and 5mL Johnson's Baby Shampoo) in order to improve connectivity between the scalp and the electrode. After soaking for a period of 5 minutes, the net was placed on the participant's head. In order to ensure correct placement (Figure 6.5), a small cross was made in the centre of the scalp, marking the intersection of the line connecting the two ears, and the line connecting the bridge of the nose (the nasion) with the inion on the back of the skull. The electrode marked VREF was placed on this cross. Once the net was in place, its position was verified by an experienced investigator with reference to a standardised diagram.

Figure 6.5. The placement of a 128-sensor EGI net on the head.
Photograph taken from Nunez (2002).

After the net was in place, electrode impedances were measured, and electrodes were manipulated until impedances were less than 50kΩ. Lower impedances indicate that the signal was of higher quality. Figure 6.6 shows the numbering of electrodes in the net. When impedances were satisfactory, the testing session began. During recording, amplified analog voltages (0.1-100Hz bandpass, -3dB) were digitized at 250Hz. Recordings were referenced online to the vertex electrode (VREF). The onset and offset of each stimulus, and the response made by the participant, were recorded by E-Prime and flagged on the NetStation recording.

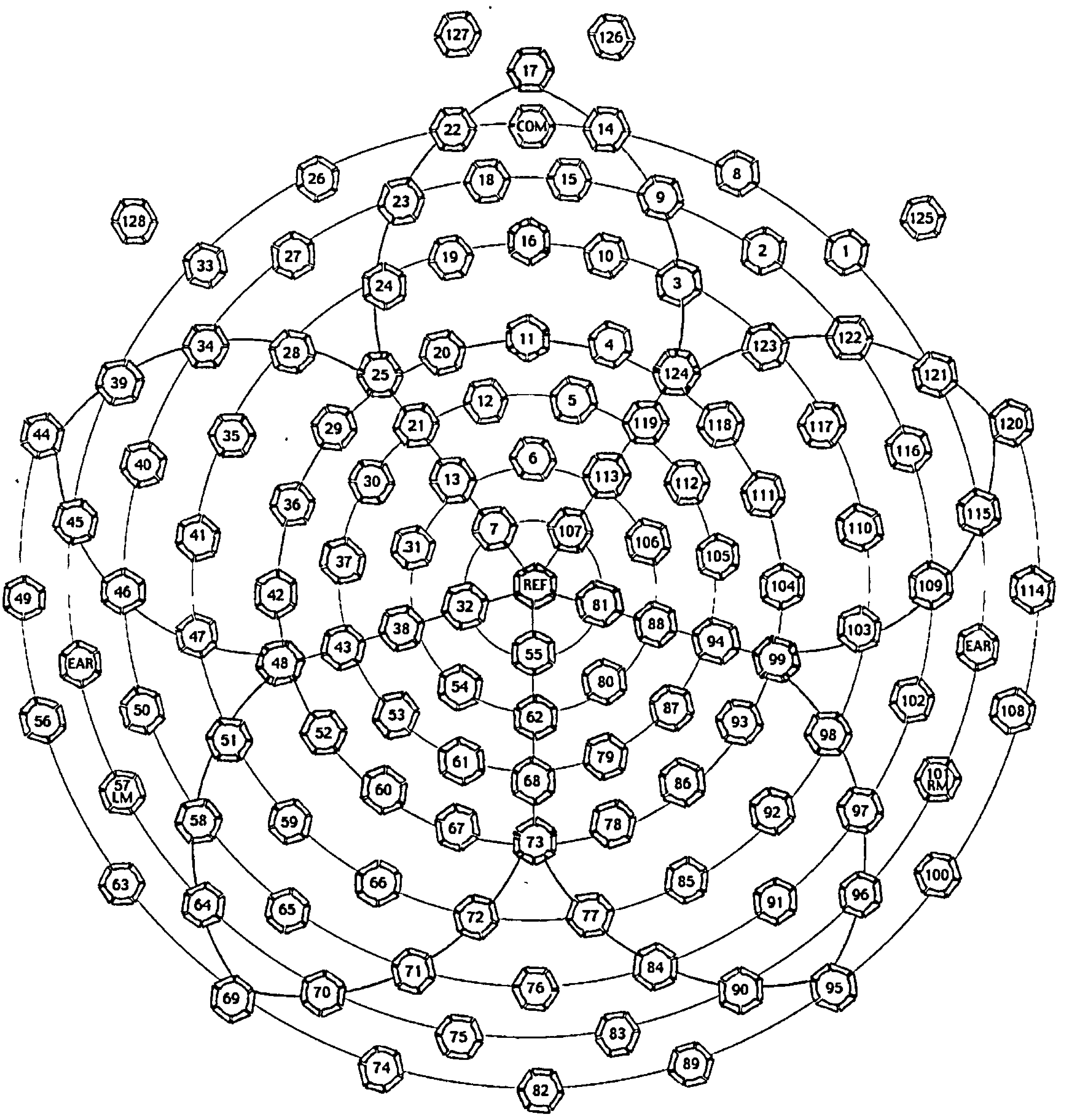

Figure 6.6. The layout of electrodes in the 128-sensor EGI net.
Figure taken from the manufacturer's website (www.egi.com).

6.3.3.4. ERP Processing

Recordings were processed offline using NetStation Waveform Tools. The recordings were digitally low-pass filtered at 30Hz, and were segmented into epochs starting 100ms before stimulus onset, and terminating 1000ms after stimulus offset. Recordings for each trial were baseline-corrected with respect to the 100ms prestimulus recording interval. Trials were digitally analysed and manually checked to ascertain whether they met any of the exclusion criteria. These included eye movements (increase in signal at electrodes 49, 39, 128, 125, 121, 120 of >70μV), blinking (increase in signal at the ocular electrodes (127 and 128) of >80 μV), or more than 13 'bad' channels (average amplitude over 200μV, transit amplitude over 100ms, or with impedance > 50kΩ). Trials were also excluded if the participant made an incorrect response. At this point, the number of good trials in each condition was totalled. Data from participants with fewer than 16 good trials in any one condition were excluded (n=11). This criterion level has been used many times in published studies (e.g., Curran & Cleary, 2003; Donaldson & Rugg, 1999; Graham & Cabeza, 2001; Rugg *et al.*, 1998; Tsivilis *et al.*, 2001). To equate the number of trials entered into the average for each participant across conditions, trials were randomly discarded from conditions with greater numbers of good trials (Thomas, Grice, Najm-Briscoe & William Miller, 2004). The average number of good trials per condition for each of the included participants was 39.9 (range 27-58). This 56% acceptance rate was comparable to others reported in published studies (e.g., 60%, Curran & Friedman, 2004; 58%; van Hooff, 2005; 47%, Wolk *et al.*, 2006).

Subsequently, the remaining recordings were averaged within each condition for each participant. Individual bad channels were replaced on a trial-by-trial basis with a spherical spline algorithm (Srinivisan, Nunex, Silberstein, Tucker & Cadusch, 1996). Consistently bad channels for a given subject were replaced throughout that subject's database (bad channels per subject ranged from 0-4, M = 0.9, median = 0). Finally, recordings were re-referenced with respect to an average reference, in order to minimise the effect of specific activity at the vertex site (Dien, 1998a). Average references were calculated for each channel as the voltage difference between that channel and the average of all channels. A grand average of the waveforms for all fifteen subjects was produced, to facilitate the identification of appropriate regions of interest.

6.3.4. Results

6.3.4.1. Behavioural data

Behavioural data were obtained from 26 participants, of which 15 provided EEG data that could also be analysed. To assess whether there were any difference in performance between participants whose EEG data could be included in the study, and those whose data were excluded, mean Hit Rates (for the *Same Context* and *Different Context* stimuli), and mean False Alarm rates were compared with two-tailed independent samples t-tests for participants who did or did not contribute EEG data. There were no significant differences on any measure (all $p > 0.05$), confirming that participants who contributed EEG data were a representative subset.

Data from the fifteen participants that contributed EEG data were then analysed in the same way as for Experiment 7. There were no significant differences between mean accuracy or reaction time in any of the counterbalancing conditions, and no effects of gender, so analyses are collapsed across these variables (all $p < 0.05$). Furthermore, as in Experiment 7 there were no significant differences in reaction time across any of the conditions (presented in Table 6.1), so this variable will not be discussed further.

Figure 6.4 shows the mean accuracy of participants in each condition. D' was also calculated. A two tailed paired-samples t-test compared Hit Rate and d' scores for the *Same Context* and *Different Context* stimuli. Both measures indicated that participants recognised significantly more stimuli in the *Same Context* than the *Different Context* condition (for Hit Rate: $t\ (14) = 2.12, p = 0.05$; for d': $t\ (14) = 2.19, p = 0.046$). This indicates that the context shift employed in Experiment 8 had a significant effect on memory retrieval. In addition to replicating the *2-Day Delay* results of Experiment 7 across a different context change, the fact that behavioural measures of memory were affected by the context change used in Experiment 8 provides a mandate for exploring the neural correlates of a context-shift effect with this dataset.

To assess whether performance was equivalent in Experiments 7 and 8, hit rates for the *2-Day Delay* condition of Experiment 7, and for Experiment 8, were entered into a Repeated-Measures ANOVA with Condition (*Same Context* or *Different Context*) as the Within-Subjects factor, and Experiment (1 or 2) as a Between-Subjects factor. This revealed a significant main effect of Condition (F (1,25) = 9.922, p = 0.004), but no significant interaction between Condition and Experiment (F (1,25) = 0.182, *n.s.*). There was no main effect of the Between-subjects variable, Experiment (F (1,25) = 1.425, *n.s.*). A similar analysis on d' scores revealed the same results: a main effect of Condition (F (1,25) = 4.48, p = 0.044), and no other significant effects. This indicates that participants performed better on the *Same Context* stimuli than the *Different Context* stimuli in both Experiments (Figure 6.4), but that scores were not significantly different across the two Experiments. The context-shift effects observed in Experiments 7 and 8 were, therefore, generalisable across different types of room change, and the effect was replicable.

6.3.4.2. EEG data

In high-density electrode EEG research, components of interest are measured within certain time windows (defined relative to stimulus onset), and across certain electrode groupings (defined by their numbers that specify the position of the electrode within the net and hence on the scalp). These windows and groupings are initially chosen with reference to the literature, and refined through examination of the grand average waveform produced in the study. This refinement is necessary to ensure that the component of interest is included within the time window analysed, and that groupings of electrodes include electrodes with similar waveform morphologies. Finally, individual average waveforms are examined for each component, to ensure that the groupings and windows chosen covered the components of interest for each participant's data.

Waveforms are averaged across the electrodes included in each grouping, and the data are then analysed within the window identified. Notably, in previous studies of context-shift effects the mean amplitude of components has been most informative (e.g., Curran, 2000; Curran & Cleary, 2003; Curran & Dien, 2003; Ecker *et al.*, 2007a,b; Groh-Bordin *et al.*, 2005; Scholerscheidt & Rugg, 2004; Tsivilis *et al.*, 2001), and it is this measurement that was used to analyse the two components in the present data set. Mean amplitude data are calculated across the whole time window selected, and are particularly important for the analysis of components that do not have a defined peak, but are rather a prolonged positive- or negative-going deflection.

There were two components of interest in the present study: a frontal negativity apparent between approximately 300 and 500ms after stimulus onset (FN400), and a parietal positivity apparent between approximately 500 and 800ms after stimulus onset (LPC). These components were analysed for each trial upon which participants made a correct response (e.g., Ecker *et al.*, 2007a,b; Tsivilis *et al.*, 2001). There were too few incorrect responses that were not accompanied by significant artifacts in the EEG data to conduct a valid analysis for incorrect trials.

6.3.4.2.1. FN400

In the present study, the FN400 was measured between 270 and 470ms after stimulus onset in order to capture the peak of the component within the analysis window (Figure 6.7).

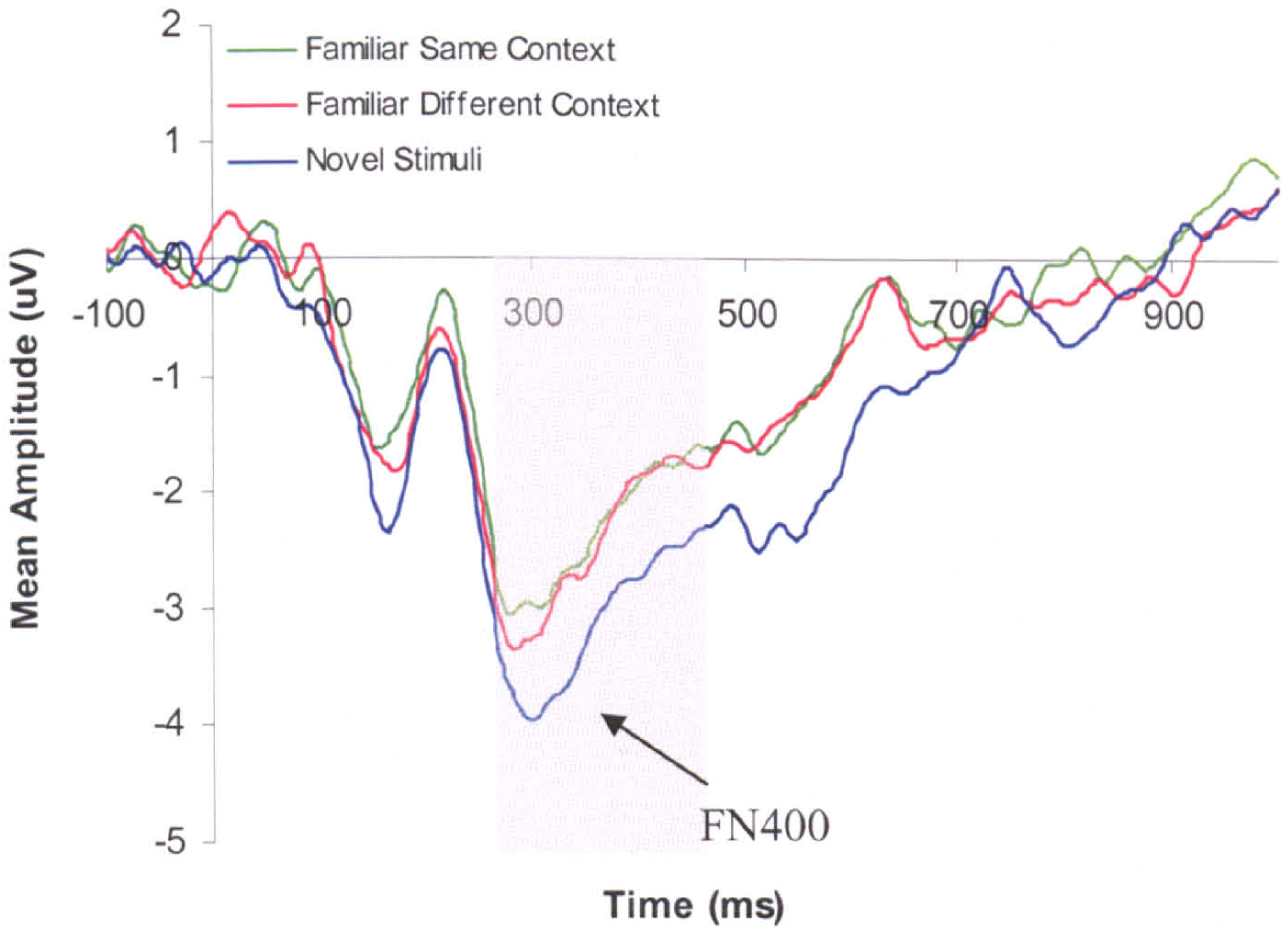

Figure 6.7. The morphology of the FN400 component.
Figure represents an average of signals measured over electrodes 12,13,19,20,21,6,7,11,16,107,10,4,5,119, and 113 across trials and participants.

The FN400 was analysed over 15 anterior superior electrodes, split into left, midline and right groupings (Figure 6.8). The left and right groupings used are comparable with previous groupings used to study the FN400, but not identical because the waveforms recorded by several lateral electrodes (numbers 25,29,30, 124,118,112) that have been used in previous studies (e.g., Curran & Cleary, 2003; Curran & Friedman, 2004) did not display an FN400 component in the present study. Including data from these electrodes may have masked any condition differences, and so analyses were restricted to a smaller subset of those used in previous studies, plus electrodes 10 and 19, which showed a marked FN400 effect. The midline electrodes were chosen following Tsivilis *et al.* (2001), who observed significant effects of a context change on signals measured over mid-frontal electrodes.

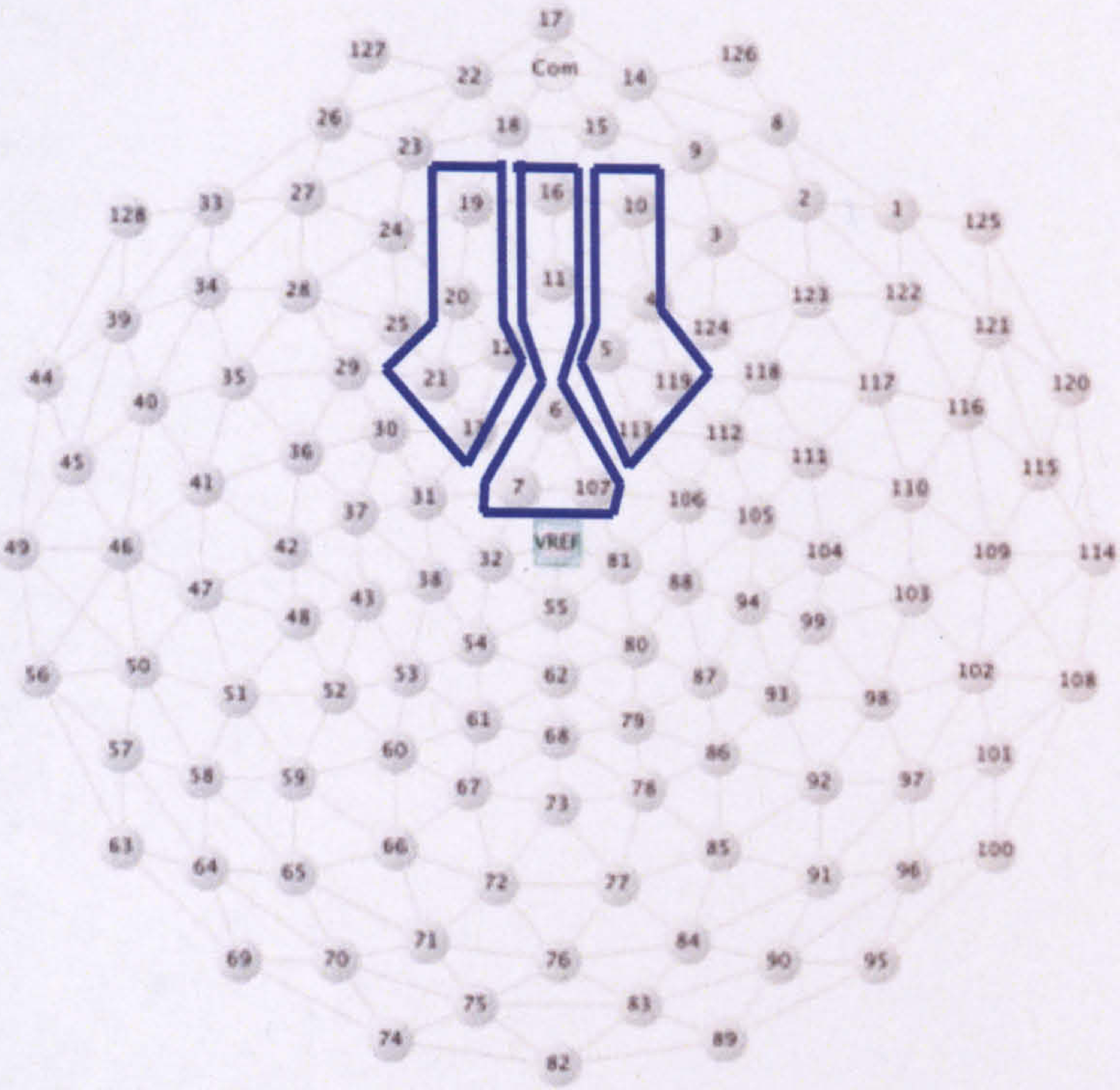

Figure 6.8. The electrode groupings used to measure the FN400 component.

The mean amplitude across the selected time window was analysed, in line with previous studies of the neural correlates of context-shift effects (Curran, 2000; Curran & Cleary, 2003; Curran & Dien, 2003; Ecker *et al.*, 2007a,b; Groh-Bordin *et al.*, 2005; Schloerscheidt & Rugg, 2004; Tsivilis *et al.*, 2001;). The data were analysed with Repeated-Measures ANOVAs corrected for non-sphericity using the Huynh-Feldt procedure, followed by planned comparisons, with a Bonferroni-correction applied.

A 3 Condition (*Same Context*, *Different Context*, or Novel) x 3 Region (Left, Midline or Right) Repeated Measures ANOVA on mean amplitude revealed a main effect of condition (F (2,28) = 5.85, $p = 0.008$); and a significant interaction between condition and region (F (4,56) = 3.103, $p = 0.022$). This indicates that differences between conditions varied according to scalp location. To investigate this further, planned comparisons of simple effects were then conducted. Separate Repeated Measures ANOVAs with Condition as a within-subject variable confirmed that the effect of condition was only present at midline (F (2,28) = 5.05, $p < 0.01$) and right hemisphere leads (F (2,28) = 9.17, $p < 0.01$); there was no significant effect of condition at left hemisphere leads (F (2, 28) = 2.80, ns). Thus, the memory effects observed in this study may have been slightly right-lateralised (Figure 6.9). Interestingly, Curran and Friedman (2004) also observed a larger difference in the mean amplitude of the FN400 to old and new object pictures over the right hemisphere, indicating that this effect may be slightly right-lateralised for nonverbal stimuli.

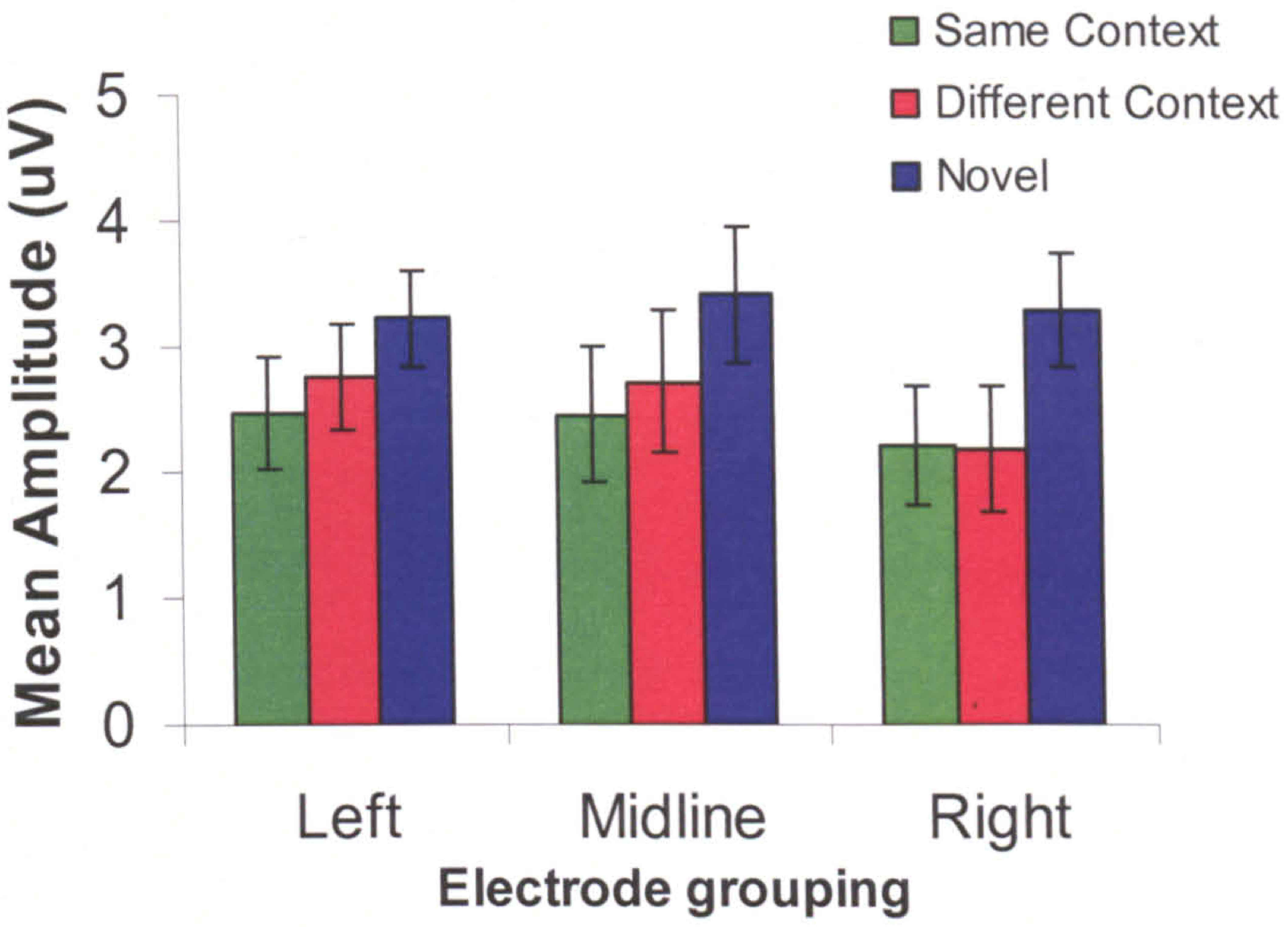

Figure 6.9. The mean amplitude of the FN400 component over left, midline and right electrodes. Figure represents the average of signals within three electrode groupings (Left: 12,13,19,20,210; Midline: 6,7,11,16,107; and Right: 10,4,5,119,113). 'Same' refers to stimuli previously studied in the testing room, 'Different' refers to familiar stimuli previously studied out of the testing room, and 'Novel' refers to stimuli that were not studied during the familiarisation session. Data represents the average from 15 participants.

To explore which conditions differed from each other, further Repeated Measures ANOVAs were conducted. A 2 Condition (*Different Context* x *Novel Context*) x 3 Region (Left, Midline or Right) ANOVA on mean amplitude revealed that the FN400 mean amplitude was significantly greater for novel pictures than for familiar pictures previously seen in a **different** room (F (1,14) = 8.843, $p = 0.01$), and that there was an interaction between the effect of Condition and the effect of Region (F (1,14 = 5.44, $p = 0.035$). This was due to a greater difference between the mean amplitude of the *Different Context* and *Novel context* conditions over the right hemisphere leads than over the left hemisphere leads. Thus, the FN400 differentiated between pictures that were novel, and familiar pictures that were previously seen in a different context.

Similarly, a 2 Condition (*Same Context* x *Novel Context*) x 3 Region (Left, Midline or Right) ANOVA on mean amplitude revealed that the FN400 mean amplitude was significantly greater for novel pictures than for familiar pictures previously seen in the **same** room ($F(1,14) = 12.476, p = 0.01$). In this case, there was no significant interaction between the effect of Condition and the effect of Region. Thus, the FN400 differentiated between pictures that were novel, and familiar pictures that had previously been seen in the same context.

However, a 2 Condition (*Same Context* x *Different Context*) x 3 Region (Left, Midline or Right) ANOVA on mean amplitude revealed that the mean amplitude of the FN400 did not differ for the two types of familiar picture ($F(1,14) = 0.247$, *n.s.*). Thus, the FN400 did not discriminate between familiar pictures that had previously been seen in the *Same Context*, or in a *Different Context*.

In summary, the FN400 showed the expected memory effect, with more negative mean amplitude to novel stimuli than to familiar stimuli, and this effect was greater over right hemisphere electrodes. However, the component did not differentiate between stimuli on the basis of the congruence of contextual information between encoding and retrieval.

6.3.4.2.2. The LPC

In the present study, the LPC was measured between 500 and 700ms after stimulus onset (Figure 6.10), in order to capture the component within the analysis window.

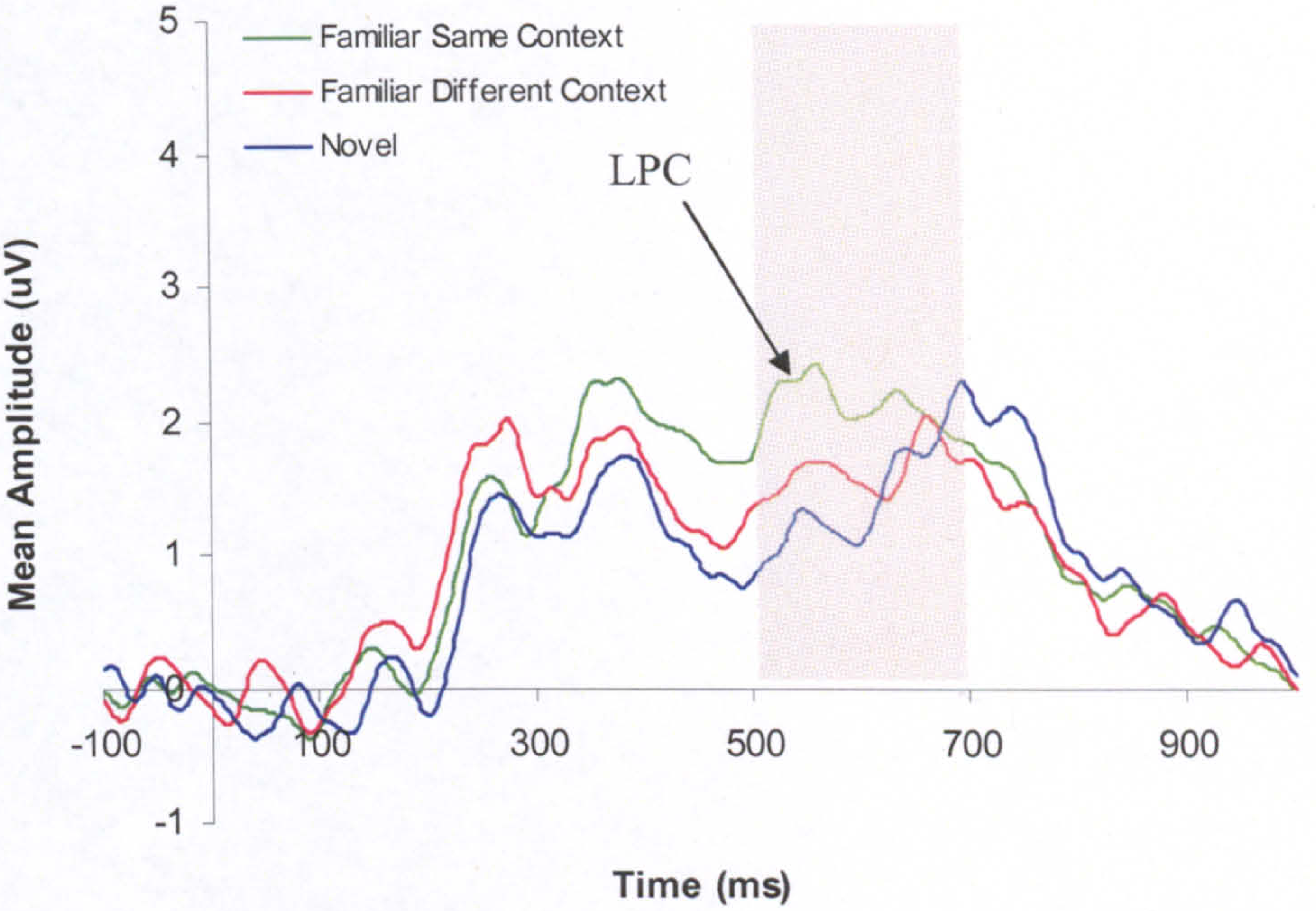

Figure 6.10. The morphology of the LPC component.
Figure represents an average of signals measured over electrodes 38,54,53,61,55,62,68,73, 79,80,87, and 88 across trials and participants.

The LPC was analysed over 12 posterior superior electrodes, split into left, midline and right groupings (Figure 6.11). The left and right groupings used are comparable with previous groupings used to study the LPC, but not identical because the waveforms recorded by several lateral electrodes (numbers 52, 43, 60, 94, 93, 86) used in previous studies (e.g., Curran & Cleary, 2003; Curran & Friedman, 2004) did not display an LPC component in the present study. Including data from these electrodes may have masked any condition differences, and so analyses were restricted to a smaller subset of those used in previous studies. The mean amplitude across the selected time window was analysed, in line with previous studies of the neural correlates of context-shift effects (Curran, 2000; Curran & Cleary, 2003; Curran & Dien, 2003; Ecker *et al.*, 2007a,b; Groh-Bordin *et al.*, 2005; Schloerscheidt & Rugg, 2004; Tsivilis *et al.*, 2001)

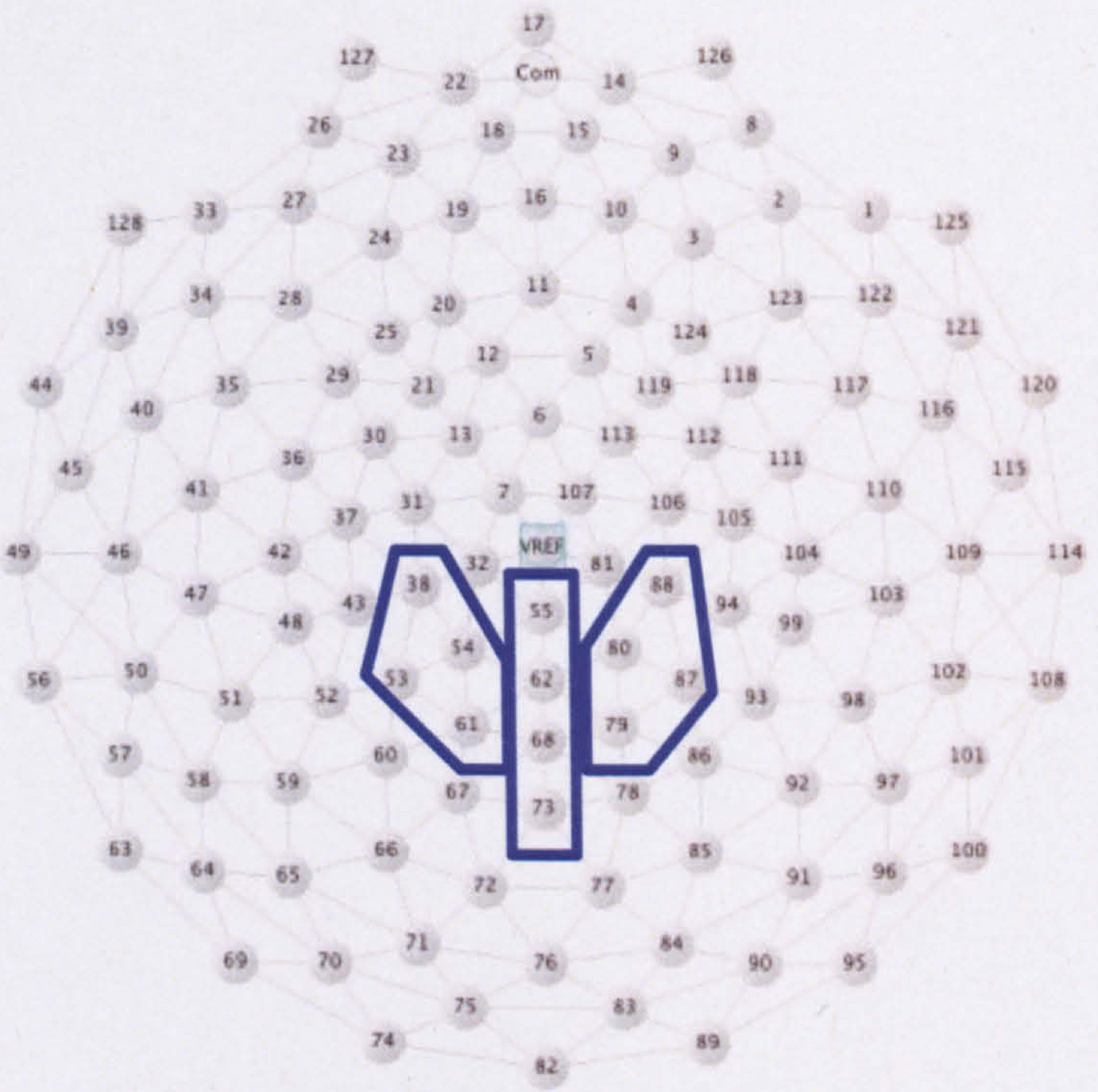

Figure 6.11. The electrode groupings used to measure the LPC component

A 3 Condition (*Same Context*, *Different Context*, or *Novel*) x 3 Region (Left, Midline or Right) Repeated Measures ANOVA on mean amplitude revealed a main effect of condition (F (2,28) = 3.42, p = 0.047). No other effects were significant ($p > 0.05$). This indicates that the LPC differentiated between the three types of picture, but did not vary according to scalp location (Figure 6.12).

To explore which conditions differed from each other, further Repeated Measures ANOVAs were conducted. A 2 Condition (*Same Context* x *Novel Context*) x 3 Region (Left, Midline or Right) ANOVA on mean amplitude revealed that the LPC mean amplitude was significantly greater for novel pictures than for familiar pictures previously seen in the **same room** (F(1,14) = 4.792, p = 0.046). In this case, there was no significant interaction between the effect of Condition and the effect of Region. Thus, the LPC differentiated between pictures that were novel, and familiar pictures that had previously been seen in the same context.

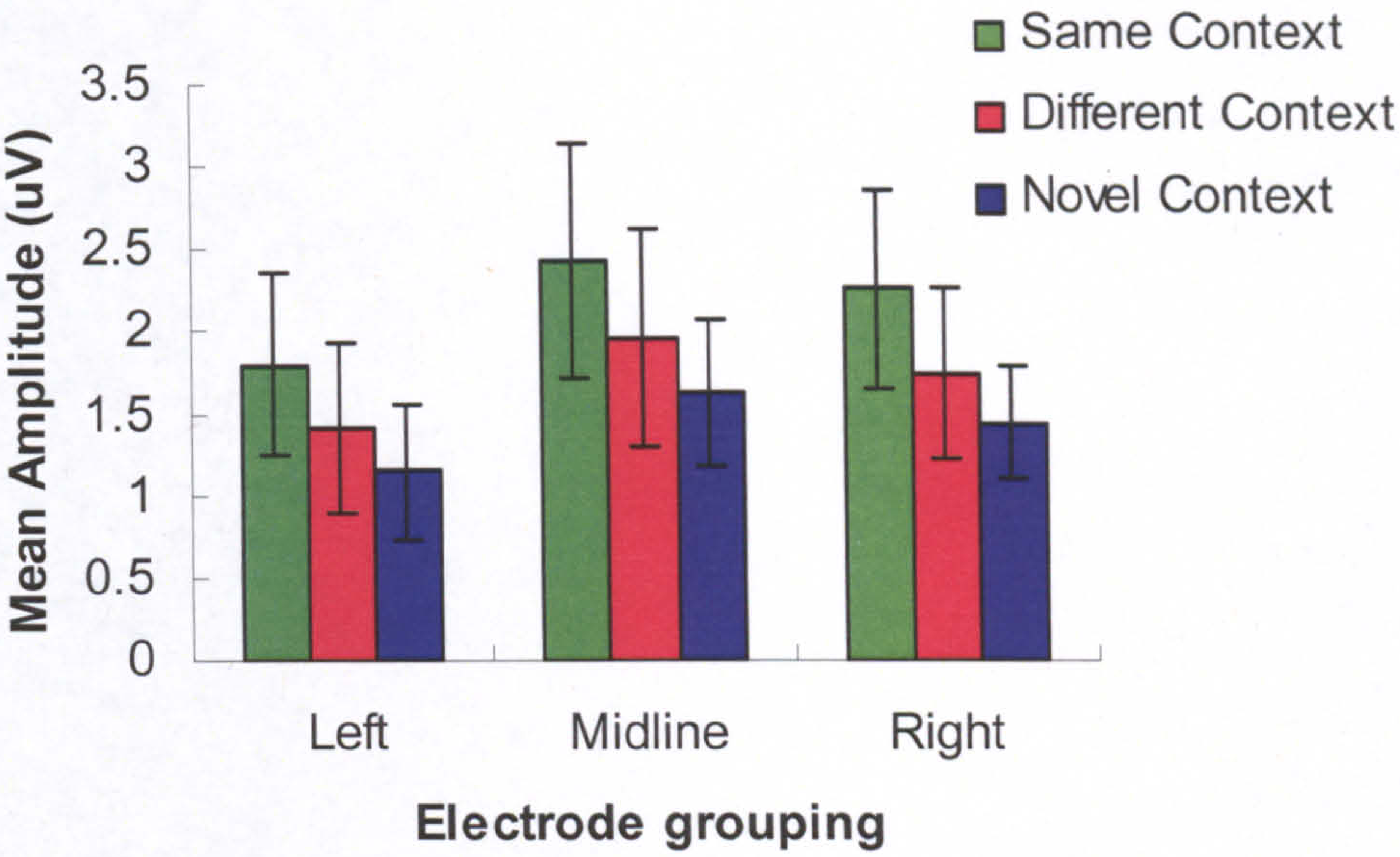

Figure 6.12. The mean amplitude of the LPC component over left, midline and right electrodes. Figure represents the average of signals within three electrode groupings (Left: 38,54,53,61; Midline: 55,62,68,73; and Right: 79,80,87,88). 'Same' refers to stimuli previously studied in the testing room, 'Different' refers to familiar stimuli previously studied out of the testing room, and 'Novel' refers to stimuli that were not studied during the familiarisation session. Data represents the average from 15 participants.

However, a 2 Condition (*Different Context* x *Novel Context*) x 3 Region (Left, Midline or Right) ANOVA on mean amplitude revealed that the LPC mean amplitude was **not** significantly greater for novel pictures than for familiar pictures previously seen in a **different room** ($F(1,14) = 1.13$, *n.s.*), and no other effects were significant (all $p>0.05$). Thus, the LPC did not differentiate between novel pictures, and pictures previously seen in a different context.

Finally, a 2 Condition (*Same Context* x *Different Context*) x 3 Region (Left, Midline or Right) ANOVA on mean amplitude revealed that there was a trend for the mean amplitude of the LPC to differ for the two types of familiar picture ($F(1,14 = 3.589$, $p = 0.08$). Thus, the LPC marginally differed between pictures that had previously been seen in the same context, and pictures previously seen in a different context.

In summary, the LPC showed the expected memory effect, with more negative mean amplitude to novel stimuli than to familiar stimuli, and this effect was equivalent across the three electrode groupings. However, this effect was only present for familiar pictures that were previously seen in the context of learning. Furthermore, the LPC appeared to differentiate between the two types of familiar picture, being marginally more positive for familiar pictures previously seen in the same context than familiar pictures previously seen in a different context.

6.3.5. Discussion of Experiment 8

Experiment 8 explored the behavioural and neural correlates of encoding and retrieving a set of pictures in different rooms in the laboratory. Replicating the findings of Experiment 7, participants were less accurate at recognizing pictures they had previously encountered in a different room that pictures they had encountered in the room of testing. As Experiments 7 and 8 were conducted at different Universities, it seems that the effect of a change of global context on memory retrieval in the present paradigm was robust.

In the EEG data, both an LPC old/new effect and an FN400 old/new effect were observed for familiar stimuli that were learned and tested in the same room. The mean reaction time of responses was over 800ms in all conditions, indicating that the FN400 and LPC (measured between 300 and 500ms, and 500 to 700ms after stimulus onset respectively) both reflected pre-response processes, rather than aspects of post-response processing. These findings extend the interval over which the FN400 has been detected from 1-day (Curran & Friedman, 2004) to 2-days, and provides further evidence to contradict the proposal that the FN400 does not reflect a longer-term memory process (Rugg, 1995). However, whereas both components showed old/new effects for familiar stimuli learned in the room of testing, only the FN400 showed an old/new effect for familiar stimuli learned in an alternate room. The LPC did not distinguish between novel pictures, and familiar pictures previously seen in a different room. Thus, it appears that a change of global context employed in this study had a negative impact on recollective memory, but not familiarity. These findings are discussed in more detail in the General Discussion.

6.4. Experiment 9: The effect of a change of background on the FN400 and LPC

The aim of Experiment 9 was to explore the effect of a change of background on familiarity and recollection in adulthood, through measuring the FN400 and LPC with EEG. The change of background used in the present study was a change from a red to a blue coloured background, or vice versa. These backgrounds were chosen because they are comparable to the brightly coloured, plain or simply patterned backgrounds used in studies of context-shift effects in infancy (e.g., Borovksy & Rovee-Collier, 1990; Robinson & Pascalis, 2004). As in Experiment 8, accuracy and reaction times provided behavioural measures of the context-shift effect. Again, the previous EEG literature makes it difficult to make a clear prediction as to the effect of a change of background on recollection and familiarity. Thus, on the basis of Macken (2002)'s proposal that recollection is more affected by a change of extrinsic context, it was tentatively predicted that a change of background colour would influence the LPC but not the FN400 in the present study.

6.4.1. Participants

Participants were 26 undergraduate students (14 female, 12 male) at the University of Sheffield, who received course credit for participation. Participants ranged in age from 18 to 27 years, (mean = 20.5, SE = 0.28). All were right-handed with normal or corrected-to-normal vision, and participants were asked not to volunteer if they had any known neurological conditions (such as epilepsy). Data from eight participants were excluded because only one of the two experimental sessions was attended, leaving a final sample size of 18 (12 female). The contextual manipulation was varied within-subjects, such that within each retention interval condition, each participant was tested for recognition of stimuli previously experienced in the context of testing (*Same Context* condition), and stimuli previously experienced in an alternate context (*Different Context* condition). All participants had normal or corrected-to-normal vision. The study was approved by the Department of Psychology ethics committee.

6.4.2. Apparatus and stimuli

Testing was conducted in the Psychology Department at the University of Sheffield. The stimuli were the same used for Experiments 7 and 8. Stimuli were presented on a desktop computer using E-prime (v 2.0) software (Psychology Software Tools, Inc).

The stimuli were presented on one of two coloured backgrounds (either red or blue), which served as the contexts (see Figure 6.13 for examples). During the familiarisation session, 72 stimuli were presented on the red background, and 72 stimuli were presented on the blue background, with the stimuli lists seen in on each background and the order of viewing counterbalanced between participants. Stimuli presented on the same background were grouped together, to render the procedure as similar as possible to that used in Experiments 7 and 8. During the test session, the 144 familiarisation stimuli and the 144 foil stimuli were presented in a randomised order. All stimuli were presented on one of the learning backgrounds (either red or blue), with the background chosen counterbalanced between participants. As in Experiments 7 and 8, a 5-minute break was inserted half-way through the test session, and a buffer stimulus was inserted at the start of each half of the test session. Responses to these two buffer stimuli, which were of the same nature as the test stimuli, were not analysed.

Figure 6.13. Examples of stimuli used in Experiment 9.

6.4.3. Procedure

For participants in all conditions, the experiment took place in two parts. In the first part, participants were allowed to view the familiarisation stimuli. In the second part, participants were tested for their recognition of these stimuli. The familiarisation and test sessions were separated by a delay of approximately 2 days (range = 42 to 52 hours, M = 47.3, SE = 0.46s). In both sessions, participants were seated 1 m away from the screen, which was 34 cm by 22 cm.

6.4.3.1. The familiarisation session

Half the participants viewed a set of 72 stimuli on Background A, before viewing a second set of 72 stimuli on Background B. The remaining participants experienced the contexts in the reverse order. Participants were told that their memory for these stimuli would subsequently be tested, so they should view each one carefully. Participants were allowed to view each stimulus for as long as they wished (M = 3.0 s, SE = 0.3s). The familiarisation session lasted approximately 20 minutes.

6.4.3.2. The test session

Half the participants were tested with stimuli presented on Background A, and half the participants were tested with stimuli presented on Background B. Thus, half the familiar stimuli had previously been experienced in the testing context (*Same Context* condition), and half had been experienced in the alternate context (*Different Context* condition). The procedure of the testing session was identical to that employed in Experiment 8, for both behavioural and EEG recording.

6.4.3.3. EEG processing

This was conducted in the same way as for Experiment 8. However, it became apparent that most participants performed too poorly to contribute sufficient trials to the EEG analysis. Only three out of the 18 participants had more than 16 analyzable trials in each of the three conditions, a number that is insufficient for credible analysis. Many participants produced few correct responses, and remaining trials were contaminated with artifacts such as blinks or movements. Since the drop-out rate was so high, it was considered that testing more participants would result in an unrepresentative final sample. Thus, only the behavioural results are presented in the Results section. Possible reasons for the poor performance seen are considered in the discussion.

6.4.4. Results

Behavioural data were obtained from 18 participants. There were no significant differences between mean accuracy or reaction time in any of the counterbalancing conditions, and no effects of gender, so analyses are collapsed across these variables (all $p > 0.05$). Furthermore, as in Experiment 7 there were no significant differences in reaction time across any of the conditions (presented in Table 6.1), so this variable will not be discussed further.

Figure 6.4 shows the mean accuracy of participants in each condition. D' was also calculated. A paired-samples t-test compared Hit Rate and d' scores for the *Same Context* and *Different Context* stimuli. Both measures indicated that participants recognised significantly more stimuli in the *Same Context* than the *Different Context* condition (for Hit Rate: $t(17) = 4.23, p = 0.001$; for d': $t(17) = 3.2, p = 0.005$). This indicates that the stimuli were more accurately remembered when they were presented on the same background during the learning and testing sessions.

In order to establish whether there were any differences between global and local extrinsic context in the present study, the behavioural results of Experiment 7 (*2-Day Delay* condition) and Experiment 9 were compared. Experiment 7 was chosen as the comparison condition because the study was run in the same University Department as Experiment 9, and with the same equipment. The only difference was that participants wore an EEG cap during the test session of Experiment 9, but not for Experiment 7. However, the fact that there were no significant differences in performance between Experiments 7 and 8 suggests that the presence of the EEG cap does not drive significant differences in accuracy.

A Repeated-Measures ANOVA on hit rates by Condition (*Same Context* or *Different Context*), with Context (Room or Background) as a Between-Subjects factor revealed a significant main effect of Condition (F (1, 28)=19.78, p <0.001), but no significant interaction between Condition and Context (*F*(1,28) =0.59, *n.s.*). There was also a main effect of the Between-subjects variable, Context (*F*(1,28) = 5.55, $p = 0.026$). A similar analysis on d' scores revealed the same results: a main effect of Condition (*F*(1,31) = 6.67, $p = 0.015$; and a main effect of Context (*F*(1,31) = 8.01, $p = 0.008$). Examination of the marginal means (Figure 6.14) reveals that participants performed better on the *Same Context* stimuli than the *Different Context* stimuli in both conditions, and performed better overall in Experiment 7 than Experiment 9.

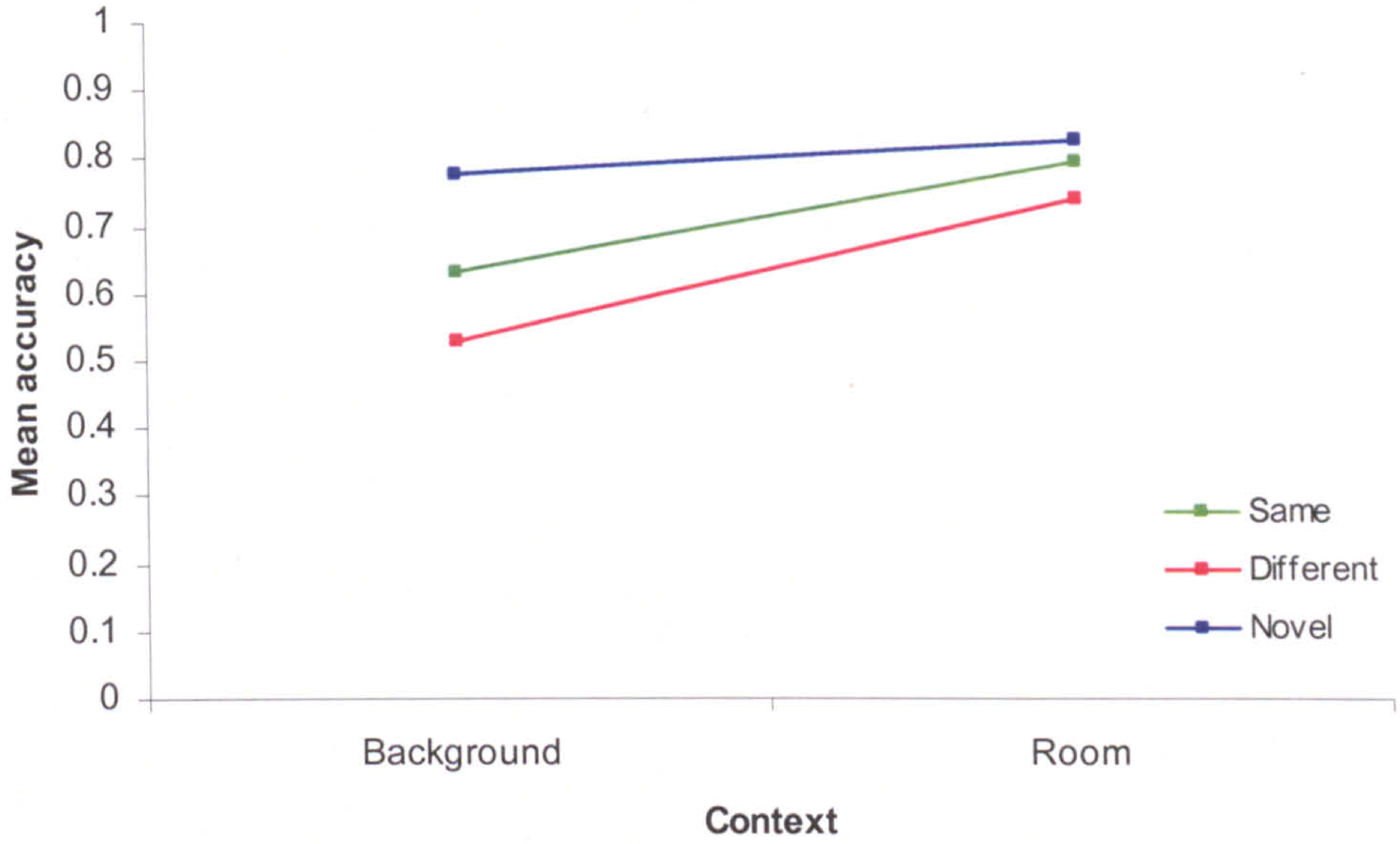

Figure 6.14. Comparison of performance in Experiments 7 (Room Change) and 9 (Background Change).
Participants performed better in Experiment 7 (*2-Day Delay* condition) than in Experiment 9 ($p<0.05$), and correctly recognised fewer stimuli when learning and testing sessions occurred in different contexts ($p<0.05$). 'Background' and 'Room' refer to the type of context changed between the familiarisation and test sessions of each study. n = 12 in the Room Change condition, and n = 18 in the Background Change condition. 'Same' refers to stimuli previously studied in the testing room, 'Different' refers to familiar stimuli previously studied out of the testing room, and 'Novel' refers to stimuli that were not studied during the familiarisation session.

However, a two-tailed independent samples t-test revealed that accuracy at identifying the novel stimuli (correct rejection rate) was not significantly different for the two Experiments (*t* (28) = 0.191, *n.s.*). Furthermore, there were no significant differences in reaction times for correct or incorrect stimuli in the two Experiments ($p>0.05$). Thus, participants were less accurate at correctly accepting familiar stimuli in Experiment 9, but were no less accurate at correctly rejecting novel stimuli.

6.4.5. *Discussion of Experiment 9*

Participants correctly recognised familiar stimuli in Experiment 9 more accurately when they were presented on the same background at encoding and retrieval. Thus, memory retrieval for young adults is influenced by a change of background, even when large numbers of stimuli are presented on the same, plain background, and participants are not given instructions to integrate stimulus and background (e.g., Ecker *et al.*, 2007a; Tsivilis *et al.*, 2001). The magnitude of the context-shift effect associated with a change of background (local extrinsic context) in Experiment 9 was equivalent to the magnitude of the context-shift effect observed with a change of room (global extrinsic context) in Experiment 7. In contrast, Dalton (1993) and Russo *et al.* (1999) found that local and global contextual stimuli had different influences on recognition memory. However, this was only the case for familiar stimuli (familiar words, or pictures that had been viewed previously); for unfamiliar stimuli, both local and global context changes impacted on retrieval. Although the stimuli used in the present study were pictures of common objects from familiar categories, the exact exemplars used were presumably unfamiliar to participants. The use of unfamiliar stimuli could explain why memory was equally context-sensitive to a change of global and local context in the present study.

Although the magnitude of the context-shift effect was equivalent in Experiments 7 and 9, overall performance was not. Accuracy of identifying the familiar stimuli (hit rate) was poorer in Experiment 9 than Experiment 7. Indeed, the low number of hits prevented the analysis of the EEG data collected. This difference in performance was unlikely to result from differences in motivation during the test session, as the mean number of correct rejections of novel stimuli was not significantly different in the two Experiments. Furthermore, the performance difference was unlikely to result from participants adopting different criterions in the two studies, as d' scores (a measure of recognition sensitivity, indicating discrimination between the familiar and novel pictures) also differed between Experiments 7 and 9. Finally, participants did not respond at significantly different speeds in the two Experiments, suggesting that participants in Experiment 9 did not perform less accurately because of a speed-accuracy trade-off. Rather, it appears that memory for the familiar stimuli was poorer in Experiment 9.

The difference in hit rates between Experiments 7 and 9 is surprising in the light of the fact that the experimental designs were highly similar. The stimuli and general procedures were identical, and the age range and educational background of participants were very similar (all being undergraduates or postgraduates at University). Finally, participants viewed the familiarisation stimuli for approximately the same mean duration in these experiments (3.4 and 3.0 seconds respectively), suggesting that familiarisation time cannot account for the differences in performance. Accuracy differences between Experiments 7 and 9 may have been driven by the fact that in Experiment 9 the stimuli were presented on brightly coloured backgrounds (Figure 6.13), whereas in Experiment 7 they were presented on black backgrounds (Figure 6.3). The brightly coloured backgrounds may have distracted participants, meaning that a greater proportion of the familiarisation period was spent attending to the background of the stimulus. (Ecker *et al.*, 2007a). This may have reduced the strength of memory for the familiar stimulus, resulting in poorer overall performance in the test session. Changes in the pattern of attention to objects and their backgrounds depending on the characteristics of the background used are an important topic for future research.

If greater attention to the background in Experiment 9 led to poorer overall performance, why were context-shift effects no different in Experiments 8 and 9? The 'one-shot context-storage hypothesis' (Malmberg & Shiffrin, 2005) proposes that on each presentation of a target stimulus, contextual information is only processed and encoded for a limited amount of time (around 1 second). After this point, context-shift effects will not increase with increased viewing of the target or its context. Thus, in Experiment 9, increased viewing to the context might not have increased contextual storage over that seen in Experiment 7, but may still have decreased the strength of the representation of the target item. Thus, it is possible that the provision of a distinctive background may impair recognition memory for human adults in some circumstances.

The neural correlates of a background colour change were not pursued further in the present study for two reasons. First, the change of room used in Experiment 8 was directly relevant to the findings presented in Chapter 3, and the neural correlates of a change of room have not been previously explored. Although a change of background colour has not been explored, other studies have explored the influence of a change of background scene (e.g., Ecker *et al.*, 2007; Piatt *et al.*, unpublished; Tsivilis *et al.*, 2001). Second, changing the procedure used in Experiment 9 in order to improve performance, for example by giving participants longer to learn the stimuli, would have meant that those results could not have been directly compared with the findings of Experiment 8. Thus, the neural correlates of a change of background colour remain a topic for further research.

6.5. General Discussion

6.5.1. The influence of a context-shift on recognition accuracy

Adults were significantly more accurate in recognizing object stimuli when the objects had been previously been learned in the testing room than in an alternate room (Experiments 7 and 8). Comparable findings were obtained when the contextual manipulation was a change from one colour of background to another (Experiment 9). Importantly, adult participants were not instructed to pay attention to the room of learning or the background upon which stimuli were presented. This made conditions in the present study more similar to those used to explore context-shift effects in infancy than are adult studies in which participants have been instructed to integrate the target times with their contexts (e.g., Ecker *et al.*, 2007b; Tsivilis *et al.*, 2001). Furthermore, the background colours used in Experiment 9 of the present study were a subset of those used in previous infancy research (e.g., Robinson & Pascalis, 2004), and the rooms used in Experiment 7 were highly similar to those used to explore the influence of a change of room on recognition memory in infancy in Experiments 1 and 2. These results indicate that human adults are influenced by the same types of contextual change that influence memory in infancy when the two groups are tested in age-appropriate tasks.

6.5.2. The neural correlates of a change of room

In Experiment 8, the LPC, but not the FN400, was sensitive to a room change. In the majority of studies, the LPC has been associated with recollection-based recognition memory, and the FN400 has been associated with familiarity-based recognition memory (reviewed by Rugg & Curran, 2007), and the weight of evidence in favour of this distinction was considered in the Introduction. Thus, the present results may indicate that recollective-based recognition memory is more sensitive to a change of room than familiarity-based recognition memory. However, it is important to briefly evaluate alternative interpretations.

6.5.3. The LPC and FN400 are unlikely to represent memory 'strength'

Many dual-process models propose that a recognition memory decision tends to be based on either recollection or familiarity (e.g., Yonelinas, 1994). However, a recent dual-process model of recognition memory challenged the proposal that recollection and familiarity produce independent contributions to recognition memory, instead proposing that recollection and familiarity sum to produce an overall level of activation upon which a recognition decision is based (reviewed by Wixted, 2007). Wixted's model, in common with more traditional single-process models, would assume that the FN400 and LPC reflect different activation strengths of the same general signal (Rugg & Curran, 2007). Because ERPs are identified through averaging a large number of trials, it may be that the FN400 and LPC come from different groups of trials on which participants remembered more or less well. Thus, it could be argued that the LPC was selectively affected by a context-shift because it reflected memory retrieval that differed in strength from that reflected by the FN400. However, in the present study there was no correlation between recognition memory accuracy and the magnitude of a context-shift effect, suggesting that a relationship between memory strength and the effect of a context-shift was not apparent.

6.5.4. Face recognition studies have identified different neural correlates of familiarity and recollection

Although the majority of studies that have used verbal stimuli, nameable objects, or abstract pictures as stimuli have associated the FN400 and LPC with familiarity and recollection, two studies with face stimuli have linked different patterns of neural activity to these two processes (Yovel & Paller, 2004; Mackenzie & Donaldson, 2006). If faces do not elicit the classic neural responses to familiarity and recollection, the comparability of the present study to Experiments 1 and 2 (which used faces as stimuli) is called into question. However, Curran and Hancock (2007) used face stimuli and did identify the classic FN400/LPC pattern. Thus, it is possible that specific aspects of the procedures used by Yovel and Paller (2004) and Mackenzie and Donaldson (2006) created the unusual waveforms obtained. One candidate may be the low discriminability of the faces used in these studies. This may reduce the degree to which familiarity can distinguish between target items and distracters, thus altering the neural signals generated (Curran & Hancock, 2007). Thus, the FN400 and LPC can be detected with a wide range of stimuli, although procedural variation might affect their expression in certain cases.

6.5.5. The FN400 is unlikely to reflect conceptual priming

In the present study, the stimuli were pictures of common objects, many of which may have activated 'concepts' when viewed by participants. When the same stimuli were viewed during the test session, these concepts would once again have been activated. Conceptual priming refers to the case in which this subsequent activation is facilitated for the familiar stimuli. Conceptual priming would presumably not occur for the novel stimuli, whose concepts have not previously been activated in the study. Some authors have argued that conceptual priming could explain the old/new sensitivity of the FN400 effect (e.g., Voss & Paller, 2006; Yovel & Paller, 2004). However, the view that the FN400 reflects conceptual priming has been robustly challenged by a number of authors (e.g., Curran & Hancock, 2007; Curran, Tanaka & Weiskoff, 2002; Groh-Bordin *et al.*, 2006). One piece of evidence contradicting the conceptual priming hypothesis is the observation that the FN400 old/new effect occurs for stimuli unlikely to have conceptual representations, like novel dimensional shapes (Curran *et al.*, 2002; Groh-Bordin *et al.*, 2006). Thus, it appears unlikely that the FN400 reflects conceptual priming alone.

In summary, there is strong evidence that the FN400 and LPC reflect familiarity and recollection respectively, with alternative proposals attracting less support. Thus, the present study provides evidence that a change of global extrinsic context (the room in which participants were tested) influences the neural correlates of recollection, but not familiarity.

6.5.6. The influence of a change of distal context on recollection, but not familiarity

The present data accords with the proposal that 'environmental' context-shift effects might be greater for recollection than for familiarity (e.g., Mandler, 1980; Macken, 2002). Indeed, this proposal is a particularly attractive one, because it accords with natural experiences of recollection and familiarity, such as the 'Butcher on the Bus' phenomenon (Mandler, 1980). Most have had the experience of meeting someone who appears familiar, but whose identity is not immediately retrievable. This experience tends to occur when the person is seen somewhere he is not typically encountered – for example, when the Butcher is seen on the bus. Mandler (1980) argued that recollection is impaired by meeting someone out of context, whilst familiarity remains intact, explaining why recognition memory measures may sometimes be unaffected by a context change. In the present study, a change of room influenced the neural correlates of recollection, but not familiarity, providing evidence in support of this proposal. However, EEG measures are only one of a number of procedures that can be used to distinguish recollection and familiarity (reviewed by Yonelinas, 2002). In order to strengthen this conclusion it would be necessary to explore the effects of a change of room on recollection and familiarity when the two processes are dissociated in other ways, such as the remember/know procedure (Tulving, 1985), or the process-dissociation procedure (Jacoby, 1991).

6.5.7. Different types of context may have different influences on the neural correlates of recognition memory

In the present study, a change of global extrinsic context influenced the neural correlates of recollection but not familiarity. Ecker *et al* (2007b) found that a change of intrinsic context (the colour of the stimulus) affected the neural correlates of familiarity but not recollection, whereas a change of local extrinsic context (the background of the stimulus) affected the neural correlates of both recollection and familiarity. Thus, it appears that moving from intrinsic, to local extrinsic, to global extrinsic context co-occurs with a shift in the locus of the context-shift effect from being mainly familiarity-based, to being mainly recollective-based.

What could account for this shift? Intrinsic contextual information, such as the colour of a target item, may be integrated into memory with the representation of the target item itself (Ecker *et al.*, 2007b). The intrinsic contextual information would then add to the general familiarity signal when it is congruent between encoding and retrieval. When the intrinsic contextual information is incongruent between encoding and retrieval, the familiarity signal is reduced, thus creating a context-shift effect on the FN400. Local extrinsic context (such as a change of background) may be incorporated into representations of the target items and thus affect the familiarity signal, and/or be associated with target items, influencing memory retrieval through recollection (e.g., Ecker *et al.*, 2007b; Piatt *et al.*, unpublished). Notably, when items are clearly separated from their backgrounds, the familiarity signal is less influenced by a background change than when items are not clearly separated from their backgrounds (Ecker *et al.*, 2007a). This may reflect the fact that the background is more likely to be integrated with the target item, and thus modulate the familiarity signal, when it is less easily separated from the item itself.

Global extrinsic contextual information, such as the room of testing, is presumably less likely to be integrated into the representation of each target item because it is more separated in time (being present before, during and after the item presentation) and space (being diffuse and non-specifically associated with the item). This could explain why a change of global extrinsic context had no effect on the neural correlates of familiarity in the present study (see Macken, 2002 for a similar argument). Contextual information may have instead been linked to target information through an associative mechanism, where item and context are linked in memory, but are also maintained as separable representations (e.g., Jaeger *et al.*, 2006). With associative representations, a context change reduces the number of retrieval cues for each item, reducing the recollective signal, as was seen in the present study.

6.5.8. Implications for infant memory

One aim of the present study was to provide data that could be used to shed light on mechanisms of context-shift effects in infant memory. The present data provide evidence that a change of room influences recollection-based recognition memory in adulthood. Thus, the influence of a change of room on recognition memory in 6- to 18-month-old infants in Chapter 3 may have been mediated by recollective-based recognition memory. Indeed, it has been argued that the particular recognition task used in that Chapter (the VPC) loads heavily on recollective-based recognition (Pascalis *et al.*, 2004). The decreasing effect of a change of room between the ages of 6- and 12-months in Chapter 3 may thus indicate age-related improvements in recollective memory. This proposal is supported by the observation that similar age-related changes in the effect of a change of global context on memory retrieval are seen in the deferred imitation paradigm (Hayne *et al.*, 2000). Deferred imitation may require recollection because perceptually absent information must be retrieved. Both deferred imitation and the VPC may thus show context-shift effects in infancy because they both rely heavily on recollective memory. However, it is important to recognise that infants may not use the same memory processes as adults when faced with the same task. Developing a method to directly examine the influence of a contextual change on recollection and familiarity in infancy would be valuable.

6.5.9. Identifying similar infant components

In the future, EEG measurements may provide one way to examine recollection and familiarity in development. Identifying components that may be infant analogues of the FN400 and LPC may be one step towards this goal, although it is unlikely that they would appear in their adult form in an infant EEG trace. Changes in the size and composition of the brain and skull, myelination (which increases the speed of processing), changes in neural connectivity, neural migration and differentiation, proliferation and pruning, and changes in cognitive processes driven by maturation and learning, may all alter ERP components over development (reviewed by Nelson & Monk, 2001). Nonetheless, it is important to explore correspondences (if they exist) between infant and adult components, because this would provide a means to investigate the development of neural processing over a wider age range (e.g., Nelson, Thomas, de Haan & Wewerka, 1998; Wewerka & Luciana, 1999).

Two memory-related components have so far been identified in EEG studies with infants. The first, often called the Nc, is a frontocentral negative deflection between 400 and 800ms after stimulus onset (e.g., Bauer, Wiebe, Carver, Waters & Nelson, 2003; Carver *et al.*, 2000; de Haan & Nelson, 1997). The magnitude of the Nc may be modulated by memory for the evoking stimulus (Bauer *et al.*, 2003; Carver *et al.*, 2000). The second memory component that has been explored is the Positive Slow Wave (PSW). This is a positive-going deflection observed over central or fronto-central leads, which is observed from around 1100ms after stimulus onset (e.g., Nelson, 1994). The component may be evoked by stimuli that the infant has only partially encoded, and some authors have argued that the PSW reflects memory updating (for discussion see de Haan & Nelson, 1997). Exploring the relationship between the Nc and the PSW in infancy, and the adult FN400 and LPC, may provide a starting point for studying the role of recollection and familiarity in infancy. Future examinations of the role of memory processes like recollection and familiarity in underlying context-shift effects in infancy may provide greater insight into early memory development.

Chapter 7: Conclusions

The present series of studies explored contextual influences on memory retrieval, and their development. Experiments 1 to 4 revealed more about the effect of a change of social or physical context on recall and recognition memory in infancy; Experiments 5 and 6 added to our understanding of the factors that control generalisation across an intrinsic context change; and Experiments 7 to 9 provided insight into the processes that mediate contextual influences on memory retrieval, using a procedure that could be easily adapted for use with an infant population. Issues arising from these studies, their limitations, and suggested avenues for future research are presented in this Chapter.

7.1. Infants remember a wide range of contextual features

The first aim of the present thesis was to further specify the role of social and physical context in memory in infancy. By the logic of the encoding specificity principle (Tulving & Thompson, 1973), if performance on a memory task is poorer after a context change, the participant must have distinguished the retrieval context from their memory of the learning context. Exploring context-shift effects in infancy can thus reveal the range of contextual details infants encode in memory. In previous research, 6- to 12-month-old infants could distinguish between two highly familiar contexts (rooms in the home; Hartshorn *et al.*, ,1998b), could determine whether a social or physical context was novel or familiar (Hayne *et al.*, 2000; Learmonth *et al.*, 2005), and could learn and remember very simple contextual features (such as the colour of the background of a stimulus) when tested in a familiar (Borovsky & Rovee-Collier, 1990) or an unfamiliar environment (Robinson & Pascalis, 2004). Extending these results, Experiments 1 and 2 found that 6- to 18-month-old infants encoded sufficient contextual features of a novel room during a one-minute familiarisation period to distinguish it from a second novel room. Furthermore, Experiments 3 and 4 found that 6 and 9-month-old infants represented and remembered relatively detailed social contextual information, such that they distinguished between two equally familiar young, female experimenters. These findings indicate that at 6-months, infants are already able to rapidly encode and remember relatively detailed information about the social and physical context of an event.

The present studies also provide evidence that the same types of contextual change influence memory in both infancy and adulthood. In Experiments 7 to 9, recognition memory in adulthood was significantly influenced by a context change over a 2-day delay, when context was defined as either the colour of the background upon which stimuli were presented, or the room in which the experiment was conducted. These two types of context change also influence recognition memory in infancy (Robinson & Pascalis, 2004; Experiments 3 and 4), albeit over shorter retention intervals and with fewer learned stimuli. Furthermore, a change of experimenter has a large impact on recall and recognition memory in adulthood (Smith & Vela, 2001) and in infancy (Chapter 4). Taken together, these studies suggest that the same kinds of contextual information influence memory retrieval across the lifespan, undermining the proposal that there is a qualitative change from context-free to context-rich memory during the infancy period (e.g., Nadel *et al.*, 1985; Nadel & Zola-Morgan, 1984; see also Schacter & Moscovitch, 1984).

7.3. Factors that influence generalisation in infancy

The ability to retrieve memory across contextual changes is commonly termed 'generalisation'. Early in infancy, generalisation appears very limited: contextual changes do not simply decrease memory performance, as they do for adults, but appear to preclude memory retrieval altogether (reviewed by Rovee-Collier, 2001; Rovee-Collier *et al.*, 2001). Therefore, generalisation is a skill that infants must develop. The sentiment that "when stimulus generalisation occurs, it can be viewed as simply the failure of the subject to have established a discrimination between the original stimulus and the new one" (Reber, 1995) is inappropriate when considering generalisation in infancy. For example, in Experiment 5, 12-month-old infants produced fewer target actions after a change in the form of a stimulus, but they still produced more target actions than infants who had never seen the actions demonstrated. This indicates that infants both discriminated the training stimulus from the original stimulus, and partially generalised across the change. In Experiment 2, 12- and 18-month-old infants recognised a stimulus across a change of room, but exhibited a different pattern of behaviour than when they were tested in the room of learning. In Experiment 4, 9-month-old infants recognised a stimulus across a change of social context, but showed a different preference direction than when tested in the social context in which learning took place. In both experiments, infants discriminated between the learning context and an altered test context, but also generalised across this change. During the first and second years of life, generalisation does not necessarily result from forgetting of contextual information.

As contextual forgetting is not the sole determinant of generalisation, the second aim of the present thesis was to identify other driving factors. Experiment 6 provided evidence that for 12-month-old infants, generalisation across a change in intrinsic context can be facilitated by the provision of a unique location for learning and retrieval. This facilitatory effect was robust across a number of variations in the encoding procedure (Experiment 5). Similarly, an opportunity to link the learning and test sessions through associating the demonstration and test experimenters in the room of learning facilitated generalisation for 6-month-old infants (Experiment 3c). The provision of retrieval cues through associative memory may thus be a particularly important determinant of generalisation in infancy. Indeed, memory for associations between physical stimuli to be important in generalisation in 6-month-old infants (e.g., Barr *et al.*, 2001, 2002, 2003; Cuevas *et al.*, 2007), and the present work suggest this may extend to other domains (such as social information) and other age groups (such as 12-month-old infants). As infants build an integrated knowledge of the world around them, their ability to generalise across a contextual change is likely to progressively improve.

7.3. Contextual influences on memory retrieval in different paradigms

The present studies provided further evidence that there are broad improvements in generalisation across the first year of life (Hartshorn *et al.*, 1998b; Hayne *et al.*, 2000; Robinson & Pascalis, 2004). The precise developmental patterns observed in the present study were strengthened by their consistency across recall (deferred imitation) and recognition (VPC) memory measures. For example, in Experiments 3 and 4 a change of social context appeared to preclude both recall and recognition memory for 6-month-old infants, but neither recall nor recognition for 9-month-old infants. Although the recall and recognition procedures used in Experiments 3 and 4 were highly similar, congruency in the effects of a context change on recall and recognition memory can also be identified when comparing across studies that have utilised very different procedures. For example, in Experiments 1 and 2 a change of global physical context (room in the lab) appeared to preclude recognition memory for 6- month-old infants, but not for 12-month-old infants. Similarly, Hayne *et al* (2000) found that a change of global physical context (from home to lab) precluded recall memory for 6- but not 12-month-old infants. Converging evidence from different paradigms reduces the plausibility of task-specific explanations for context-shift effects in infancy. Importantly, recall the lack of correlation between scores on deferred imitation and VPC tasks (Gross *et al.*, 2004), even when the procedures used are virtually identical (Experiment 4). This indicates that congruency in the influence of a context change on the VPC and deferred imitation procedures is unlikely to be related to a third variable that links performance on the two tasks. Rather, there appear to be broad changes in the influence of context on memory retrieval during the first year of life.

The timescale over which these changes occur does not appear to be uniform across different types of context. For example, in the VPC a change of the colour of the background upon which a stimulus is presented precludes recognition memory for 12- but not 18-month-old infants (Robinson & Pascalis, 2004), whereas a change of room precludes recognition for 9- but not 12-month-old infants (Experiments 1 and 2). Furthermore, a change of experimenter preclude recall memory in a deferred imitation task for 6- but not 9-month-old infants (Experiment 3), whereas a change of intrinsic context continues to have a strong influence in the same procedure at the age of 12-months (Experiment 5; Hayne *et al.*, 2000). These disparities indicate that in infancy, as in adulthood (Section 1.9.3), contextual influences on memory retrieval depend on the details included in the definition of 'context'. The pattern of attention paid to contextual details may play some role in the age at which infants begin to generalise across particular contextual changes. For example, details of the stimulus may be more salient than extrinsic contextual details (Experiment 6; Hayne *et al.*, 2000) because infants spend more time looking at the stimulus than the surrounding context (Figure 4.8). Enhanced attention to the stimulus and its immediate surroundings may explain why a coloured background exerts a particularly constraining influence on memory in the VPC task (Robinson & Pascalis, 2004). Examining patterns of attention during the learning and testing sessions of different procedures may reveal more about the relationship between contextual encoding and subsequent contextual influences on retrieval.

Alternatively, the timing of exposure to the contextual information in relation to the exposure of the target information may be important (Dalton, 1993). For example, in the procedures used in this thesis, infants first encountered the experimenter, then the room of testing, and details of the stimulus were simultaneously presented with the target information. This is the inverse of the order in which infants learn to generalise across these contextual changes. Infants may habituate to contextual features that are first presented some time before the target information, and may thus be less likely to form an association between the two. It has long been known that younger infants habituate more slowly than older infants (e.g., Fantz, 1964), and may thus be more likely to associate a wider range of contextual features to the target information. Exploring the relationship between the timing of exposure to contextual information and the magnitude of context-shift effects may shed light on this possibility.

7.4. What causes developmental change?

The third aim of the present thesis was to explore the processes that might underlie developmental changes in contextual influences on memory retrieval in infancy. Although age-related changes in patterns of attention to contextual features may play a role in developmental changes in generalisation, they cannot account for the full range of data. For example, in Experiment 4 memory retrieval in 9-month-old infants was less affected by a social context change than in 6-month-old infants, despite the fact that both age groups looked at the experimenter for the same amount of time (in both relative and absolute terms) during the learning and test sessions. In this section, three theories that provide alternative explanations for age-related increases in generalisation are briefly considered in the light of the data obtained in the present thesis.

7.4.1. Are 6-month-old infants 'Map Makers'?

Rovee-Collier and colleagues have proposed that 6-month-old infants are particularly sensitive to contextual changes because they are constructing a representation of the environment that they can utilise when they begin to crawl: they are 'map-makers' (Rovee-Collier, 1996; Hartshorn *et al.*, 1998b). 'Map-maker' theory proposes that a sharpened memory for the last location in which a stimulus was encountered enables infants who have just begun to crawl to locate that stimulus more readily. Through crawling or other forms of independent locomotion (which tend to emerge between 6- and 10-months), infants construct a cognitive map of the environment that enables them to relate familiar locations together (Benson & Uzgiris, 1995; Yan, Thomas & Downing, 1998). When this occurs, "the memories of events that transpired in those places also become associated with each other" (Rovee-Collier, 1996, p 393). Rovee-Collier (1996) proposes that this leads to increased generalisation in infants of 9-months and older, as is seen in the train task when infants are trained and tested in different rooms at home (Hartshorn *et al.*, 1998b). In line with this proposal, infants who are crawling are more likely to show generalisation than infants who are not (Herbert, Gross & Hayne, 2006).

Although the functional perspective espoused by the idea of 'map-makers' is undoubtedly valuable, the range of data it can account for is relatively limited. For example, in Experiments 1 and 2 a change of room in the lab precluded memory retrieval for 6- and 9-month-old infants, but not 12- or 18-month-old infants. This does not accord with a general reduction in contextual sensitivity between 6- and 9-months. However, 9-month-old infants may not have generalised their knowledge from one room to another in Chapter 3 because they were tested in a novel environment, for which they had no opportunity to construct a cognitive map. If this were the case, 'map-maker' theory fails to provide an account of why 12- and 18-month-old infants were able to do so. Finally, 'map-maker' theory does not clearly generalise to the concurrent changes seen in the influence of social context on memory retrieval (Experiments 3 and 4). Thus, 'map-maker' theory does not provide a comprehensive account of the development of generalisation in infancy, although the fact that measures of motor development were not taken in the present studies must be taken into consideration.

7.4.2. Representational flexibility

A number of authors have proposed that age-related increases in generalisation represent increases in 'representational flexibility' (e.g., de Haan *et al.*, 2006; Hayne, 2004; Richmond & Nelson, 2007; Robinson & Pascalis, 2004). This has been attributed to the development of the hippocampus (De Haan *et al.*, 2006), or more specifically the dentate gyrus (Richmond & Nelson, 2007). Could this account for the present results? In order for generalisation in infancy to be ascribed to representational flexibility, it is important to demonstrate that the contextual attributes in question have been encoded and remembered, as was seen in Experiments 1, 2 and 4. Secondly, it is important to demonstrate that the tasks used to assess memory rely on hippocampally-dependent memory processes. Although this presently cannot be directly determined, there is indirect evidence that the VPC and deferred imitation tasks used in Experiments 1 to 6 rely on hippocampal functioning (reviewed in Sections 2.2.3 and 2.3.3). Methodological advances that enable the investigation of neural processes in the developing brain (such as Near Infra-Red Spectroscopy, or NIRS) may enable these links to be tested directly in the near future.

For generalisation to be conclusively linked to representational flexibility, the contextual change in question must have predominantly influenced memory through the incorporation of contextual information into relational representations. This may be particularly difficult to demonstrate. However, dual-process models have been linked to relational memory theory (RMT), with recollection being most closely associated with relational memory representations (e.g., Eichenbaum *et al.*, 1994). For example, both recollection and relational memory are thought to be critically dependent on the hippocampus (reviewed by Diana *et al.*, 2007; Eichenbaum *et al.*, 2007; Yonelinas, 2002). Experiment 8 provided evidence that the influence of a change of room on recognition memory in adulthood is likely to be mediated through recollective-based, rather than familiarity-based, recognition memory processes. Other behavioural evidence also suggests that changes in 'environmental' context affect recollection but not familiarity (Macken, 2002). Thus, a change of room may have a selective effect on relational memory in adulthood. If a change of room also has a selective influence on recollective memory in infancy (a possibility that remains to be tested directly), age-related decreases in the effect of a change of room on memory retrieval (e.g., Experiments 1 and 2) may be related to changes in aspects of relational representations, such as representational flexibility. However, this proposition has yet to be tested directly, and no evidence is available concerning the inclusion of other types of context in fused or relational representations. Furthermore research is clearly required before any firm conclusions can be drawn.

7.4.3. The development of the frontal cortex

Conjunctive memory theory (CMT) provides an alternative explanation for age-related increases in generalisation. Under CMT, sparse representations in the dentate gyrus and CA3 lead to the separation of different episodes in memory. Generalisation occurs either when two episodes are very similar, in which case pattern completion in the hippocampus can retrieve memory of one from the other, or through the interaction between the hippocampus and the frontal cortex (see Section 1.6.2). In infancy, the dentate gyrus is immature (Seress, 2001). For example, cells do not appear adult-like until 12-15-months, and the number of synapses does not begin to increase until 8- to 12-months. Thus, it is plausible that the dentate gyrus (part of the hippocampus) produces even sparser representations in early infancy than it does in adulthood. This would make pattern completion less likely, rendering generalisation more dependent on the frontal cortex, which also has a relatively slow developmental trajectory (reviewed by Diamond, 2002). Thus, increases in generalisation across infancy could be related to improvements in the function and connectivity of the frontal cortex, and reductions in the sparseness of representations in the dentate gyrus. The advantage of CMT is that it has been computationally implemented (Atallah *et al.*, 2004; Norman & O'Reilly, 2003). It would be particularly interesting to alter the parameters of the model to match what is known about the developing brain, and examine how the output of the model changes as areas such as the dentate gyrus develop. This may not only provide insight into infant memory development, but also provide a novel test of the predictions of CMT.

7.5 Limitations

Although cross-sectional studies like those in the present thesis can provide valuable information about the average performance of infants at particularly ages, unlike longitudinal studies they do not provide information about the developmental trajectories of individual infants. Longitudinal studies may provide stronger evidence concerning the order in which infants become able to generalise across different types of context. Longitudinal studies would also enable contextual influences on memory to be more closely referenced to developmental milestones, which is important because generalisation has been linked to the onset of crawling (Herbert *et al.*, 2007) and the development of self-awareness (Prudhomme, 2005). Furthermore, the present studies did not explore the effect of individual differences on group scores. This means that the influence of variables such as motor and cognitive development, parental socio-economic status, the existence of older siblings, or whether the infant attends a nursery were not assessed. Any of these factors may influence the trajectory of memory development, and further studies may provide insight into factors that affect patterns of development in individual infants. For example, it may be particularly interesting to explore the development of contextual influences on memory retrieval in infants from different cultures, in the light of research showing cultural differences in the magnitude of context-shift effects with adults (reviewed by Nisbett, 2003).

The present explorations all involved stimuli that were novel to the infant. Using novel stimuli enables levels of stimulus exposure to be standardised, and reveals the contextual constraints on memory retrieval when infants learn about a stimulus for the first time. However, it is important to recognise that this may not provide a balanced reflection of the degree to which contextual information constrains memory retrieval in the infant's natural environment. For adults, context exerts fewer constraints on the retrieval of familiar stimuli (e.g., Dalton, 1993; Russo *et al.*, 1999). Infants may be more adept at generalising across contextual changes when remembering stimuli that they have encountered on several previous occasions. Furthermore, the present studies were all conducted in a laboratory environment. Again, this allowed the features and familiarity of the learning context to be standardised within and between age groups, and reveals the contextual constraints on memory retrieval when infants learn something in an unfamiliar setting. However, the applicability of the present results to infants learning at home is unclear. Directly comparing the role of context in memory when infants are tested with novel and familiar stimuli, or in novel and familiar environments, may be important in determining how research in the laboratory is related to infants learning in their home environment.

The present studies explored memory over short retention intervals, in order to avoid confounding age-related changes in contextual influences on memory with age-related changes in retention duration. However, it is clear that context plays a different role in memory retrieval when memory is tested over different retention intervals (see Section 1.9.1 for review). Furthermore, the manner in which contextual influences change over time has been a matter of some debate (e.g., Bouton *et al.*, 1999; Riccio *et al.*, 1999). Clarifying the manner in which the influence of a context change alters over time for infants of different ages, with different context changes and in different procedures may broaden our understanding of contextual influences on memory retrieval in infancy.

7.6. Avenues for future research

Focusing on the mechanisms of change is the next step for research on contextual memory development. One promising avenue may be the examination of the neural correlates of recollective- and familiarity-based recognition memory (Chapter 6). This may enable the processes underlying the influence of a context change on memory retrieval to be mapped in more detail in the infancy period. Other brain imaging methods (such as Near Infra-Red Spectroscopy) are becoming increasingly available, and could be used to examine the structures that are involved in context memory in infancy. An alternative way to examine the processes underlying contextual influences on memory in infancy is to examine the variables that facilitate generalisation. Establishing how the factors controlling generalisation change over development may provide further insight into the mechanisms through which contextual information exerts control over memory retrieval.

The present studies explored the ability to encode and retrieve memories in different contexts. However, actively utilising contextual information to differentiate between episodes is also an important skill. For example, rats are able to use contextual information to predict which of two stimuli predicts reward (e.g., Good & Honey, 1991), and human adults can use contextual information to predict the location of a target stimulus (reviewed by Chun, 2000). There are developmental changes across human infancy in the ability to use local landmarks to predict the location of a salient event, such as an experimenter playing peek-a-boo (Acredolo & Evans, 1980; Lew, Bremner & Lefkovitch, 2000). However, little is known about whether infants can use contextual information outside the realm of spatial memory, and how this develops over the first years of life. Testing whether infants can utilise associations between objects and their contexts may reveal more about contextual memory in infancy. Furthermore, this may enable contextual memory in infancy to be related to the development of source memory (memory for the context in which an item was original presented) in childhood (e.g., Drummey & Newcombe, 2002; Sluzenski, Newcombe & Kovacs, 2006).

Finally, almost all studies of memory in infancy have involved relatively unfamiliar experimenters testing the infants. However, the majority of learning in infancy occurs in the presence of highly familiar individuals, such as family members or nursery staff. This may be a particularly important consideration when learning occurs through social interaction, such as in the deferred imitation procedure. Exploring how memory is influenced by the nature and behaviour of the infant's learning partner is particularly important for understanding the generalisability of our present knowledge of infant memory. Furthermore, it may shed light on how individual differences in the infant's social and physical environment impact on their later cognitive and social progress.

7.7. Conclusion

Exploring contextual influences on memory retrieval reveals the extent to which infants can use their previous experiences to shape future behaviour. The present data, in combination with other published work, shows there are broad contextual constraints on memory retrieval at 6-months that extend across the physical and social domains, and to both recall and recognition memory. However, these constrains progressively loosen over the first year of life, such that by 12-months infants are able to retrieve their memories in different locations, with different people, and with nonidentical toys, although the latter ability remains limited. Studying contextual memory in infancy can also provide a theoretical perspective on infant memory development. Simple theories that propose a shift from 'context-free' to 'context-rich' memory are inconsistent with the developmental data presented here and elsewhere. Alternative theories are promising, such as the proposal that representational flexibility increases over development, but they require more scrutiny. Using electrophysiological methods such as EEG to study the processes underlying memory retrieval may provide neurocognitive insights into the mechanisms of developmental change in contextual memory in the infancy period.

References

Abravanel, E. (1991). Does immediate imitation influence long-term memory for observed actions? *Journal of Experimental Child Psychology, 51*, 235-244.

Abravanel, E., & Gingold, H. (1985). Learning Via Observation During the Second Year of Life. *Developmental Psychology, 21*, 614-623.

Acredolo, L., & Evans, D. (1980). Developmental changes in the effects of landmarks on infant spatial behaviour. *Developmental Psychology, 16*, 312-318.

Adlam, A.-L., Vargha-Khardem, F., Mishkin, M., & de Haan, M. (2005). Deferred Imitation of Action sequences in Developmental Amnesia. *Journal of Cognitive Neuroscience, 17*, 240-248.

Aggleton, J. P., & Brown, M. W. (1999). Episodic memory, amnesia and the hippocampal - thalamic axis. *Behavioral and Brain Sciences, 22*, 425-489.

Aggleton, J. P., & Waskett, L. (1999). The ability of odors to serve as state-dependent cues for real world memories: Can Viking smells aid the recall of Viking experiences? *British Journal of Psychology, 90*, 1-8.

Allan, K., Wilding, E., & Rugg, M. D. (1998). Electrophysiological evidence for dissociable processes contributing to recollection. *Acta Psychologica, 98*, 231-252.

Allison, T. (1984). Recording and interpreting event-related potentials. In E. Donchin (Ed.), *Cognitive Psychophysiology: Event-Related Potentials and the study of cognition*. Hillsdale, NJ: Lawrence Erlbaum.

Altman, J., & Bayer, S. (1975). Postnatal development of hippocampal dentate gyrus under normal and experimental conditions. In R. L. Isaacson & K. H. Pribram (Eds.), *The hippocampus: Structure and development* (Vol. 1, pp. 95-122). New York: Plenum Press.

Amabile, T. A., & Rovee-Collier, C. (1991). Contextual Variation and Memory Retrieval at 6 Months. *Child Development, 62*, 1155-1166.

Arnold, S. E., & Trojanowski, J. Q. (1996). Human fetal hippocampal development I: Cytoarchitecture, myeloarchitecture and neuronal morphologic features. *Journal Of Comparative Neurology, 367*, 274-292.

Atallah, H. E., Frank, M. J., & O'Reilly, R. C. (2004). Hippocampus, cortex, and basal ganglia: Insights from computational models of complementary learning systems. *Neurobiology of Learning and Memory, 82*, 253-267.

Bachevalier, J., Brickson, M., & Hagger, C. (1993). Limbic-dependent recognition memory in monkeys develops early in infancy. *Neuroreport, 4*, 77-80.

Bachevalier, J., & Vargha-Khadem, F. (2005). The primate hippocampus: ontogeny, early insult and memory. *Current Opinion in Neurobiology, 15*, 168-174.

Baddeley, A. D. (1982). Domains of recollection. *Psychological Review, 89*, 708-729.

Bahrick, L., Hernandez-Reif, M., & Pickens, C. L. (1997). The effect of retrieval cues on visual preferences and memory in infancy: Evidence for a four-phase function. *Journal of Experimental Child Psychology, 59*, 343-371.

Bahrick, L., & Pickens, C. L. (1995). Infant Memory for Object motion across a Period of Three Months: Implications for a Four-Phase Attention Function. *Journal of Experimental Child Psychology, 59*, 343-371.

Baker, J. R., Bezance, J. B., Zellaby, E., & Aggleton, J. P. (2004). Chewing gum can produce context-dependent effects upon memory. *Appetite, 2, 154-158.*

Balsam, P. D., & Tomie, A. T. (1985). *Context and Learning*. Hillsdale, N.J.: Lawrence Erlbaum.

Barks, J. D., Sun, R., Malinak, C., & Silverstein, F. S. (1995). gp120, an HIV-1 protein, increases susceptibility to hypoglycemic and ischemic brain injury in perinatal rats. *Experimental Neurology, 132*, 123-133.

Barnat, S. B., Klein, P. J., & Meltzoff, A. N. (1996). Deferred imitation across changes in context and object: Memory and generalization in 14-month-old infants. *Infant Behavior & Development, 19*, 241-251.

Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24-month- old infants. *Infant Behavior & Development, 19*, 159-170.

Barr, R., & Hayne, H. (1996). The effect of event structure on imitation in infancy: Practice makes perfect? *Infant Behavior and Development, 19*, 253-257.

Barr, R., & Hayne, H. (2000). Age-related changes in imitation: implications for memory development. In C. Rovee-Collier, L. P. Lipsitt & H. Hayne (Eds.), *Progress in Infancy Research* (Vol. 1). Hillsdale, N.J.: Erlbaum.

Barr, R., & Hayne, H. (2003). It's not what you know, it's who you know: older siblings facilitate imitation during infancy. *International Journal of Early Years Education, 11*, 7-21.

Barr, R., Marrot, H., & Rovee-Collier, C. (2003). The role of sensory preconditioning in memory retrieval by preverbal infants. *Learning and Behaviour, 31*, 111-123.

Barr, R., Vieira, A., & Rovee-Collier, C. (2001). Mediated imitation in 6-month-olds: Remembering by association. *Journal of Experimental Child Psychology, 79*, 229-252.

Barr, R., Vieira, A., & Rovee-Collier, C. (2002). Bidirectional priming in infants. *Memory & Cognition, 30*, 246-255.

Bauer, P. J. (1996). What do infants recall of their lives? *American Psychologist*, 29-41.

Bauer, P. J. (2004). Getting explicit memory off the ground: Steps towards construction of a neuro-developmental account of changes in the first two years of life. *Developmental Review, 24*, 343-378.

Bauer, P. J., Burch, M. M., & Kleinknecht, E. E. (2002). Developments in early recall memory: Normative trends and individual differences. In *Advances in Child Development and Behavior*, (Vol. 30, pp. 103-152).

Bauer, P. J., & Mandler, J. M. (1989). One Thing Follows Another: Effects of Temporal Structure on 1- to 2-Year-Olds' Recall of Events. *Developmental Psychology, 25*, 197-206.

Bauer, P. J., & Mandler, J. M. (1992). Putting the Horse Before the Cart: The Use of Temporal Order in Recall of Events by One-Year-Old Children. *Developmental Psychology, 28*, 441-452.

Bauer, P. J., & Thal, D. J. (1990). Scripts or Scraps - Reconsidering the Development of Sequential Understanding. *Journal of Experimental Child Psychology, 50*, 287-304.

Bauer, P. J., Van Abbema, D. L., & de Haan, M. (1999). In for the short haul: immediate and short-term remembering and forgetting by 20-month-old children. *Infant Behavior and Development, 22*, 321-343.

Bauer, P. J., Wiebe, S. A., Carver, L. J., Waters, J. M., & Nelson, C. A. (2003). Developments in long-term explicit memory late in the first year of life: Behavioral and electrophysiological indices. *Psychological Science, 14*, 629-635.

Bauer, P. J., Wiebe, S. A., Waters, J. M., & Bangston, S. K. (2001). Re-exposure breeds recall: Effects of experience on 9-month- olds' ordered recall. *Journal of Experimental Child Psychology, 80*, 174-200.

Benes, F., Turtle, M., Khan, Y., & Farol, P. (1994). Myelination of a key relay zone in the hippocampal formation occurs in the human brain during childhood, adolescence and adulthood. *Archives of General Psychiatry, 51*, 477-484.

Benson, J. B., & Uzgiris, I. C. (1985). Effect of self-initiated locomotion on infant search activity. *Developmental Psychology, 21*, 923-931.

Bertsch, S., & Sanders, R. E. (2005). Age differences in context-cue forgetting. *Psychological Reports, 96*, 879-888.

Bigelow, A. E., & Birch, S. A. J. (1999). The effects of contingency in previous interactions on infants' preference for social partners. *Infant Behavior and Development, 22*, 367-382.

Boller, K., Grabelle, M., & Rovee-Collier, C. (1995). Effects of Postevent Information on Infants Memory for a Central Target. *Journal of Experimental Child Psychology, 59*, 372-396.

Boller, K., & Rovee-Collier, C. (1992). Contextual Coding and Recoding of Infants Memories. *Journal of Experimental Child Psychology, 53*, 1-23.

Boller, K., Rovee-Collier, C., Gulya, M., & Prete, K. (1996). Infants' memory for context: Timing effects of postevent information. *Journal of Experimental Child Psychology, 63*, 583 - 602.

Bornstein, M. H., Arterberry, M. E., & Mash, C. (2004). Long-term memory for an emotional interpersonal interaction occurring at 5 months of age. *Infancy, 6*, 407-416.

Borovsky, D., & Rovee-Collier, C. (1990). Contextual Constraints on Memory Retrieval at 6 Months. *Child Development, 61*, 1569-1583.

Bouton, M. (1993). Context, Time and Memory Retrieval in the Interference Paradigms of Pavlovian Learning. *Psychological Bulletin, 114*, 80-99.

Bouton, M., & Bolles, R. C. (1979). Contextual control of the extinction of conditioned fear. *Learning and Motivation, 10*, 445-466.

Bouton, M. E., Nelson, J. B., & Rosas, J. M. (1999). Stimulus Generalisation, Context Change, and Forgetting. *Psychological Bulletin, 125*, 171-186.

Brasser, S. M., & Spear, N. E. (2004). Contextual conditioning in infants, but not older animals, is facilitated by CS conditioning. *Neurobiology of Learning and Memory, 81*, 49-59.

Bretherton, I., & Ainsworth, M. (1974). Responses of one-year-olds to a stranger in a strange situation. In M. Lewis & L. Rosenblum (Eds.), *The origins of fear*. New York: Wiley.

Buffalo, E. H., Ramus, S. J., Clark, R. E., Teng, E., Squire, L. R., & Zola, S. M. (1999). Dissociation between the effects of damage to perirhinal cortex and area TE. *Learning & Memory, 6*, 572-599.

Burgess, N., Maguire, E. A., & O'Keefe, J. (2002). The human hippocampus and spatial and episodic memory. *Neuron, 35*, 625-641.

Bushnell, E. (2001). Mother's face recognition in newborn infants: Learning and memory. *Infant and Child Development, 10*, 67-74.

Bushnell, I. G. R., McCutcheon, E., Sinclair, J., & Tweedlie, M. E. (1984). Infants' delayed recognition for color and form. *British Journal of Developmental Psychology, 2*, 11-17.

Bushnell, E., Sai, F. Z., & Mullin, J. T. (1989). Neonatal recognition of the mother's face. *British Journal of Developmental Psychology, 7*, 3-15.

Butler, J., & Rovee-Collier, C. (1989). Contextual gating of memory retrieval. *Developmental Psychobiology, 22*, 533-552.

Campanella, J., & Rovee-Collier, C. (2005). Latent Learning and Deferred Imitation at 3 Months. *Infancy, 7*, 243-262.

Canas, J. J., & Nelson, C. A. (1986). Recognition and environmental context: the effects of testing by phone. *Bulletin of the Psychonomic Society, 24*, 407-409.

Cansino, S., Maquet, P., Dolan, R. J., & Rugg, M. D. (2002). Brain Activity Underlying Encoding and Retrieval of Source Memory. *Cerebral Cortex, 12*, 1047-1056.

Carpenter, M., Nagell, K., & Tomasello, M. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development, 63*, 176.

Carver, L. J., Bauer, P. J., & Nelson, C. A. (2000). Associations between infant brain activity and recall memory. *Developmental Science, 3*, 234-246.

Chua, H. F., Boland, J. E., & Nisbett, R. E. (2005). Cultural variation in eye movements during scene perception. *Proceedings of the National Academy of Sciences of the United States of America, 102*, 12629-12633.

Chun, M. M. (2000). Contextual cueing of visual attention. *Trends in Cognitive Sciences, 4*, 170-178.

Chun, M. M., & Phelps, E. A. (1999). Memory deficits for implicit contextual information in amnesic subjects with hippocampal damage. *Nature Neuroscience, 2*, 844 - 847.

Clark, S. E., & Gronlund, S. D. (1996). Global matching models of recognition memory: how the models match the data. *Psychonomic Bulletin & Review, 3*, 37-60.

Clark, R. E., Zola, S. M., & Squire, L. R. (2000). Impaired recognition memory in rats after damage to the hippocampus. *Journal of Neuroscience, 20*, 8853-8860.

Cleveland, A. & Striano, T. (2007). The Effects of Joint Attention on Object Processing in 4- and 9-Month-Old Infants. Infant Behavior and Development, 30 (3), 499-504.

Cohen, N. J., Poldrack, R. A., & Eichenbaum, H. (1997). Memory for items and memory for relations in the procedural/declarative memory framework. *Memory, 5*, 131-178.

Cohen, L. B., & Squire, L. (1980). Preserved learning and retention of pattern analyzing skill in amnesia: Dissociation of knowing how and knowing that. *Science, 210*, 207-209.

Cohen, D., & Strauss, M. S. (1979). Concept acquisition in the human infant. *Child Development, 50*, 419-424.

Collie, R., & Hayne, H. (1999). Deferred imitation by 6-and 9-month-old infants: More evidence for declarative memory. *Developmental Psychobiology, 35*, 83-90.

Colombo, J., Mitchell, D. W., Dodd, B., Coldren, J. T., & Horowitz, F. D. (1989). Longitudinal correlates of infant attention in the paired-comparison paradigm. *Intelligence, 13*, 33-42.

Concannon, J. T., Smith, G. J., Spear, N. E., and Scobie, S. R. (1978). Drug cues, drug states, and infantile amnesia. In F. C. Colpaert and J. A. Rosecrans (eds.), *Stimulus Properties of Drugs: Ten Years of Progress*. Amsterdam: Elsevier/North Holland Biomedical Press. pp. 353-396.

Cornell, E. H. (1974). Infants' discrimination of photographs of faces following redundant presentations. *Journal of Experimental Child Psychology, 70*, 26-53.

Cornell, E. H. (1979). Infants' recognition memory, forgetting and savings. *Journal of Experimental Child Psychology, 28*, 369-374.

Cornell, E. H., & Bergstrom, L. I. (1983). Serial-Position Effects in Infants Recognition Memory. *Memory & Cognition, 11*, 494-499.

Courage, M. L., & Howe, M. L. (1998). The ebb and flow of infants' attentional preferences: Evidence of long-term recognition memory in 3-month-olds. *Journal of Experimental Child Psychology, 70*, 26-53.

Courage, M. L., & Howe, M. L. (2001). Long-term retention in 3.5 month-olds: Familiarisation time and individual differences in attentional style. *Journal of Experimental Child Psychology, 79*, 271-293.

Courage, M. L., & Howe, M. L. (2004). Advances in early memory development: Insights about the dark side of the moon. *Developmental Review, 24*, 6 - 32.

Curran, T. (1999). The electrophysiology of incidental and intentional retrieval: ERP old/new effects in lexical decision and recognition memory. *Neuropsychologia, 37*, 771-785.

Curran, T. (2000). Brain potentials of recollection and familiarity. *Memory & Cognition, 20*, 923-938.

Curran, T. (2004). Effects of attention and confidence on the hypothesised ERP correlates of recollection and familiarity. *Neuropsychologia, 42*, 1088-1106.

Curran, T., & Cleary, A. M. (2003). Using ERPs to dissociate recollection from familiarity in picture recognition. *Cognitive Brain Research, 15*, 191-205.

Curran, T., & Dien, J. (2003). Differentiating amodal familiarity from modality-specific memory processes: an ERP study. *Psychophysiology, 40*, 979-988.

Curran, T., & Friedman, W. J. (2004). ERP old/new effects at different retention intervals in recency discrimination tasks. *Cognitive Brain Research, 18*, 107-120.

Curran, T., & Hancock, J. (2007). The FN400 indexes familiarity-based recognition of faces. *Neuroimage, 36*(2), 464-471.

Curran, T., Schacter, D. L., Johnson, M. K., & Spinks, R. (2001). Brain potentials reflect behavioural differences in true and false recognition. *Journal of Cognitive Neuroscience, 13*, 201-216.

Curran, T., Tanaka, J. W., & Weiskoff, D. M. (2002). An electrophysiological comparison of visual categorisation and recognition memory. *Cognitive, Affective and Behavioural Neuroscience, 2*, 1-18.

Curran, T., Tepe, K. L., & Piatt, C. (2006). Event-related potential explorations of dual processes in recognition memory. In H. D. Zimmer, A. Mecklinger & U. Lindenberger (Eds.), *Binding in Human Memory: A Neurocognitive Approach* (pp. 467-492). Oxford: Oxford University Press.

Dalton, P. (1993). The Role of Stimulus-Familiarity in Context-Dependent Recognition. *Memory & Cognition, 21*, 223-234.

Davachi, L., Mitchell, J. P., & Wagner, A. D. (2003). Multiple routes to memory: distinct medial temporal lobe processes build item and source memories. *Proceedings of the National Academy of Sciences, 100*, 2157-2162.

Davies, G. M. (1988). Faces and Places: Laboratory Research on Context and Face Recognition In G. M. Davies & D. M. Thomson (Eds.), *Memory in Context: Context in Memory* (Vol. Chapter 2, pp. 35-53): John Wiley & Sons Ltd.

Davinsky, A. (2004) Retrieved 4.9.07 from http://www.medscape.com/viewprogram/2889

Davis, J. M., & Rovee-Collier, C. K. (1983). Alleviated Forgetting of a Learned Contingency in 8-Week-Old Infants. *Developmental Psychology, 19*, 353-365.

De Haan, M., & Nelson, C. A. (1997). Recognition of the mother's face by 6-month-old infants: A neurobehvioural study. *Child Development, 67*, 187-210.

De Haan, M., Mishkin, M., Baldeweg, T., & Vargha-Khardem, F. (2006). Human memory development and its dysfunction after early hippocampal injury. *Trends in Neurosciences, 29*(7).

DeBoer, T., Wewerka, S., Bauer, P. J., Georgieff, M. K., & Nelson, C. A. (2005). Explicit memory performance in infants of diabetic mothers at 1 year of age. *Developmental Medicine and Child Neurology, 47*, 525-531.

DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science, 208*, 1174-1176.

DeCasper, A. J., & Spence, M. J. (1986). Prenatal maternal speech influences newborns' perception of speech sounds. *Infant Behavior & Development, 9*, 113-150.

Decety, J., Chaminade, T., Grezes, J., & Meltzoff, A. N. (2002). A PET exploration of the neural mechanisms involved in reciprocal imitation. *Neuroimage, 15*, 265-272.

Dellu, F., Fauchey, V., LeMoal, M., & Simon, H. (1997). Extension of a new two-trial memory task in the rat: Influence of environmental context on recognition processes. *Neurobiology of Learning and Memory, 67*, 112-120.

De Ungria, M., Rao, R., Wobken, J. D., Luciana, M., Nelson, C. A., & Georgieff, M. K. (2000). Perinatal iron deficiency decreases cytochrome oxidase (CytOx) activity in selective regions of neonatal rat brain. *Pediatric Research, 48,* 169-176.

Diamond, A. (1990). The development and neural bases of memory functions as indexed by the AB and delayed response tasks in human infants and infant monkeys. In A. Diamond (Ed.), *The development and neural bases of higher cognitive functions* (pp. 267-317). New York: New York Academy of Sciences Press.

Diamond, A. (1995). Evidence of robust recognition memory early in life even when assessed by reaching behaviour. *Journal of Experimental Child Psychology, 59,* 419-456.

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In D. T. Stuss & R. T. Knight (eds.), *Principles of frontal lobe function* (pp. 466-503). London: Oxford University Press.

Diamond, A., Churchland, A., Cruess, L., & Kirkham, N. Z. (1999). Early developments in the ability to understand the relation between stimulus and reward. *Developmental Psychology, 35*(6), 1507-1517.

Diana, R. A., Yonelinas, A. P., & Ranganath, C. (2007). Imaging recollection and familiarity in the medial temporal lobe: a three-component model. *Trends in Cognitive Sciences., 11*, 379-83.

Dien, J. (1998). Issues in the application of the average reference: Review, critiques and recommendations. *Behaviour Research Methods: Instruments and Computers, 30*, 34-43.

Dobbins, I. G., Rice, H. J., Wagner, A. D., & Schacter, D. L. (2003). Memory orientation and success: separable neurocognitive components underlying episodic recognition. *Neuropsychologia, 41*, 318-333.

Donaldson, D. I. (1996). The role of decision processes in remembering and knowing. *Memory & Cognition, 24*, 523-533.

Donaldson, D. I., & Rugg, M. D. (1999). Event-related potential studies of associative recognition and recall: electrophysiological evidence for context dependent recognition processes. *Cognitive Brain Research, 8*, 1-16.

Donaldson, D. I., & Rugg, M. D. (1998). Recognition memory for new associations: Electrophysiological evidence for the role of recollection. *Neuropsychologia, 36*, 377-395.

Dougal, S., & Rotello, C. M. (1999). Context effects in recognition memory. *American Journal of Psychology, 112*, 277-295.

Drummey, A. B., & Newcombe, N. S. (2002). Developmental changes in source memory. *Developmental Science, 5*, 502-513.

Dunn, J. C. (2004). Remember-know: a matter of confidence. *Psychological Review, 111*, 524-542.

Duzel, E., Vargha-Khardem, F., Heinze, H. J., & Mishkin, M. (2001). Brain activity evidence for recognition without recollection after early hippocampal damage. *Proceedings of the National Academy of Sciences, 98*, 8101-8106.

Duzel, E., Yonelinas, A. P., Mangun, G. R., Heinze, H. J., & Tulving, E. (1997). Event-related potential correlates of two states of conscious awareness in memory. *Proceedings of the National Academy of Sciences, 94*, 5973-5978.

Dwyer, D. M., Mackintosh, N., & Boakes, R. A. (1998). Simultaneous activation of the representations of absent cues results in the formation of an excitatory association between them. *Journal of Experimental Psychology: Animal Behaviour Processes, 24*, 163-171.

Eacott, M. J., & Norman, G. (2004). Integrated Memory for Object, Place, and Context in Rats: A possible Model of Episodic-Like Memory. *The Journal of Neuroscience, 24*, 1948-1953.

Earhard, M. (1967). Cued recall and free recall as a function of the number of items per cue. *Journal of Verbal Learning and Verbal Behaviour, 6*, 257-263.

Ebbinghaus, H. (1885). *Memory: A Contribution to Experimental Psychology.* New York: Teachers College, Columbia University.

Eckenhoff, M. F., & Rakic, P. (1988). Nature and fate of proliferative cells in the hippocampal dentate gyrus during life span of the rhesus monkey. *Journal of Neuroscience, 8*, 2729-2747.

Ecker, U. K. H., Zimmer, H. D., Groh-Bordin, C., & Mecklinger, A. (2007a). Context effects on familiarity are familiarity effects of context - An electrophysiological study. *International Journal of Psychophysiology, 64*, 146-156.

Ecker, U. K. H., Zimmer, H. D., & Groh-Bordin, C. (2007b). Color and Context: An ERP study on intrinsic and extrinsic feature binding in episodic memory. *Memory & Cognition, in press.*

Eich, E. (1985). Context, memory, and integrated item/context imagery. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 11*, 764-770.

Eich, E. (1995). Mood as a Mediator of Place Dependent Memory. *Journal of Experimental Psychology: General, 124*, 293-308.

Eichenbaum, H. (1997). Declarative memory: Insights from cognitive neurobiology. *Annual Review of Psychology, 48*, 547-572.

Eichenbaum, H., & Cohen, N. J. (Eds.). (2001). *From conditioning to conscious recollection: Memory systems of the brain.* New York, NY: Oxford University Press.

Eichenbaum, H., Otto, T., & Cohen, N. J. (1994). Two functional components of the hippocampal memory system. *Brain and Behavioural Sciences, 17*, 449-518.

Eichenbaum, H., Yonelinas, A. P., & Ranganath, C. (2007). The medial temporal lobe and recognition memory. *Annual Review of Neuroscience, 30*, 123-152.

Eldridge, L., Knowlton, B., Furmanski, C. S., Bookheimer, S. Y., & Engel, S. A. (2000). Remembering episodes: a selective role for the hippocampus during retrieval. *Nature Neuroscience, 3*, 1149-1152.

Emde, R., Gaensbauer, T., & Harmon, R. (1976). Emotional expression in infancy: A biobehavioural study. *Psychological Issues, 10*, 1-37.

Eriksson, P. S., Perfilieva, E., Bjork-Eriksson, T., Alborn, A. M., Nordborg, C., Peterson, D. E., Gage, F.H. (1998). Neurogenesis in the adult human hippocampus. *Nature Medicine, 4*, 1313-1317.

Fabiani, M., Gratton, G., & Coles, M. G. H. (2000). Event-related brain potentials. In J. T. Cacioppo (Ed.), *Handbook of Psychophysiology* (pp. 53-84). New York: Cambridge University Press.

Fagan, J. (1970). Memory in the infant. *Journal of Experimental Child Psychology, 9*, 217-226.

Fagan, J. (1974). Infant recognition memory: The effects of length of familiarisation and type of discrimination task. *Child Development, 45*, 351-356.

Fagan, J. (1976). Infants' recognition memory of invariant features of faces. *Child Development, 47*, 627-638.

Fagan, J. (1984). Recognition memory and intelligence. *Intelligence, 8*, 31-36.

Fagen, J. W., & Rovee-Collier, C. (1983). Memory Retrieval - a Time-Locked Process in Infancy. *Science, 222*, 1349-1351.

Fagen, J. W., Morrongiello, B. A., Roveecollier, C., & Gekoski, M. J. (1984). Expectancies and Memory Retrieval in 3-Month-Old Infants. *Child Development, 55*, 936-943.

Fagen, J. W., Prigot, J., Carroll, M., Piolo, L., Stein, A., & Franco, A. (1997). Auditory Context and Memory Retrieval in Young Infants. *Child Development, 68*, 1057-1066.

Fagen, J. W., Rovee, C. K., & Kaplan, M. G. (1976). Psychophysical Scaling of Stimulus Similarity in 3-Month-Old Infants and Adults. *Journal of Experimental Child Psychology, 22*, 272-281.

Fanselow, M. S. (1990). Factors governing one-trial contextual conditioning. *Animal Learning & Behavior, 18*, 264-270.

Fantz, R. L. (1956). A method for studying early visual development. *Perceptual & Motor Skills, 6,* 13-15.

Fantz, R. L. (1964). Visual experience in infants: Decreased attention to familiar patterns relative to novel ones. *Science, 146*, 668-670.

Farroni, T., Massaccesi, S., Menon, E., & Johnson, M. H. (2007). Direct gaze modulates face recognition in young infants. *Cognition, 102*, 396-404.

Fernandez, A., & Glenberg, A. M. (1985). Changing environmental context does not reliably affect memory. *Memory & Cognition, 13*, 333-345.

Fernandez, M., & Bahrick, L. E. (1994). Infants' sensitivity to arbitrary object-odor pairings. *Infant Behavior and Development, 17*, 471-474.

Field, T. M., Cohen, D., Garcia, R. S., & Greenberg, R. (1984). Mother-stranger face discrimination by the newborn. *Infant Behavior and Development, 7*, 19-25.

Friedman, D., & Johnson, D. E. (2000). Event-related potential (ERP) studies of memory encoding and retrieval: a selective review. *Microscopy Research and Technique, 51*, 6-28.

Gabrieli, J. D. E. (1998). Cognitive Neuroscience of Human Memory. *Annual Review of Psychology, 49*, 87-115.

Gaffan, D. (1994). Scene-specific memory of objects: A model of episodic memory impairment in monkeys with fornix transection. *Journal of Cognitive Neuroscience, 6*, 305-320.

Gardiner, J. M. (1988). Functional aspects of recollective experience. *Memory & Cognition, 16*, 309-313.

Glenberg, A. M. (1979). Component-levels theory of the effects of spacing of repetitions on recall and recognition. *Memory & Cognition, 7*, 95-112.

Godden, D. R., & Baddeley, A. D. (1975). Context-dependency in two natural environments on land and underwater. *British Journal of Psychology, 66*, 325-331.

Godden, D. R., & Baddeley, A. D. (1980). When does context influence recognition memory? *British Journal of Psychology, 91*, 99-104.

Gogtay, N., Giedd, J. N., Lusk, L., Hayashi, K. M., Greenstein, D., Vaituzis, A. C., Nugent, T.F., Herman, D.H., Clasen, L.V., Toga, A.W., Rapoport, J.L., Thompson, P.M. (2004). From the Cover: Dynamic mapping of human cortical development during childhood through early adulthood (Vol. 101, pp. 8174-8179)

Goh, J. O. S., Siong, S. C., Park, D., Gutchess, A., Hebrank, A., & Chee, M. W. L. (2004). Cortical Area Involved in Object, Background, and Object-Background Processing Revealed with Functional Magnetic Resonance Adaptation. *The Journal of Neuroscience, 24*, 10223-10228.

Goldman-Rakic, P. (1987). Development of cortical circuity and cognitive function. *Child Development, 58*, 601-622.

Good, M., de Hoz, L., & Morris, R. G. M. (1998). Contingent versus incidental context processing during conditioning: Dissociation after excitotoxic hippocampal plus dentate gyrus lesions. *Hippocampus, 8*, 147-159.

Good, M., & Honey, R. C. (1991). Conditioning and contextual retrieval in hippocampal rats. *Behavioural Neuroscience, 105*, 499-509.

Graham, R., & Cabeza, R. (2001). Dissociating the neural correlates of item and context memory: an ERP study of face recognition. *Canadian Journal of Experimental Psychology, 55*, 154-161.

Greco, C., Roveecollier, C., Hayne, H., Griesler, P., & Earley, L. (1986). Ontogeny of Early Event Memory .1. Forgetting and Retrieval by 2-Month-Old and 3-Month-Old. *Infant Behavior & Development, 9*, 441-460.

Groh-Bordin, C., Zimmer, H. D., & Ecker, U. K. H. (2006). Has the butcher on the bus dyed his hair? When color changes modulate ERP correlates of familiarity and recollection. *Neuroimage, 32*, 1879-1890.

Groh-Bordin, C., Zimmer, H. D., & Mecklinger, A. (2005). Feature binding in perceptual priming and in episodic object recognition: Evidence from event-related brain potentials. *Cognitive Brain Research, 24*, 556-567.

Gross, J., Hayne, H., Herbert, J., & Sowerby, P. (2002). Measuring infant memory: Does the ruler matter? *Developmental Psychobiology, 40*, 183-192.

Guillaume, F., & Tiberghien, G. (2005). Electrophysiological study of contextual variations in a short-term face recognition task. *Cognitive Brain Research, 22*, 471-487.

Gulya, M., RoveeCollier, C., & Merriman, J. (1996). Ontogeny of serial-list learning in infancy. *Developmental Psychobiology, 29*, 33-33.

Haaf, R. A., Lundy, B. L., & Coldren, J. T. (1996). Attention, recognition, and the effects of stimulus context in 6-month-old infants. *Infant Behavior & Development, 19*, 93-106.

Hall, G. (1996). Learning about associatively activated stimulus representations: Implications for acquired equivalence and perceptual learning. *Animal Learning & Behavior, 24*, 233-255.

Hanna, E., & Meltzoff, A. N. (1993). Peer Imitation by Toddlers in Laboratory, Home, and Day-Care Contexts - Implications for Social-Learning and Memory. *Developmental Psychology, 29*, 701-710.

Hartshorn, K., & Rovee-Collier, C. (1997). Infant learning and long-term memory at 6 months: A confirming analysis. *Developmental Psychobiology, 30*, 71-85.

Hartshorn, K., & Rovee-Collier, C. (2003). Does infant memory expression reflect age at encoding or age at retrieval? *Developmental Psychobiology, 42*, 283-291.

Hartshorn, K., Rovee-Collier, C., Gerhardstein, P., Bhatt, R. S., Wondoloski, T. L., Klein, P., Glich, J., Wurtzel, N., & Campos-de-Carvalho, M. (1998a). The ontogeny of long-term memory over the first year-and-a-half of life. *Developmental Psychobiology, 32*, 69-89.

Hartshorn, K., Rovee-Collier, C., Gerhardstein, P., Bhatt, R. S., Klein, P. J., Aaron, F., et al. (1998b). Developmental changes in the specificity of memory over the first year of life. *Developmental Psychobiology, 33*, 61-78.

Hayne, H. (2004). Infant memory development: Implications for childhood amnesia. *Developmental Review, 24*, 33 - 73.

Hayne, H., Barr, R., & Herbert, J. (2003). The effect of prior practice on memory reactivation and generalization. *Child Development, 74*, 1615-1627.

Hayne, H., Boniface, J., & Barr, R. (2000). The development of declarative memory in human infants: Age-related changes in deferred imitation. *Behavioral Neuroscience, 114*, 77-83.

Hayne, H., Greco, C., Earley, L., Griesler, P., & Rovee-Collier, C. (1986). Ontogeny of Early Event Memory .2. Encoding and Retrieval by 2-Month-Old and 3-Month-Old. *Infant Behavior & Development, 9*, 461-472.

Hayne, H., MacDonald, S., & Barr, R. (1997). Developmental changes in the specificity of memory over the second year of life. *Infant Behavior & Development, 20*, 233-245.

Hayne, H., Rovee-Collier, C., & Borza, M. A. (1991). Infant Memory for Place Information. *Memory & Cognition, 19*, 378-386.

Hayne, H., Rovee-Collier, C., & Perris, E. E. (1987). Categorization and Memory Retrieval by 3-Month-Olds. *Child Development, 58*, 750-767.

Heathcote, A., Raymond, F., & Dunn, J. (2006). Recollection and familiarity in recognition memory: evidence from ROC curves. *Journal of Memory and Language, 4*, 495-514.

Heimann, M., & Meltzoff, A. N. (1996). Deferred Imitation in 9- and 14-month-old infants: A longitudinal study of a Swedish sample. *British Journal of Developmental Psychology, 1996*, 1.

Heimann, M., Strid, K., Smith, L., Tjus, T., Ulvund, S. E., & Meltzoff, A. N. (2006). Exploring the relation between memory, gestural communication, and the emergence of language in infancy: A longitudinal study. *Infant and Child Development, 15*, 233-249.

Henson, R., Rugg, M. D., Shallice, T., Josephs, O., & Dolan, R. (1999). Recollection and familiarity in recognition memory: An event-related magnetic resonance imaging study. *Journal of Neuroscience, 19*, 3962-3972.

Herbert, J., & Hayne, H. (2000a). The ontogeny of long-term retention during the second year of life. *Developmental Science, 3*, 50-56.

Herbert, J., & Hayne, H. (2000b). Memory retrieval by 18-30-month-olds: Age-related changes in representational flexibility. *Developmental Psychology, 36*, 473-484.

Herbert, J., Gross, J., & Hayne, H. (2007). Crawling is associated with more flexible memory retrieval by 9-month-old infants. *Developmental Science, 10*, 183-189.

Hill, W. L., Borovsky, D., & Rovee-Collier, C. (1988). Continuities in Infant Memory Development. *Developmental Psychobiology, 21*, 43-62.

Hintzmann, D. L., & Curran, T. (1994). Retrieval dynamics of recognition and frequency judgements: evidence for separate processes of familiarity and recall. *Journal of Memory and Language, 33*, 1-18.

Hirsh, R. (1974). The hippocampus and contextual retrieval of information from memory: A theory. *Behavioral Biology, 12*, 421-444.

Honey, R. C., & Good, A. J. (1993). Selective hippocampal lesions abolish the contextual specificity of latent inhibition and conditioning. *Behavioral Neuroscience, 107*, 23-33.

Honey, R. C., & Good, M. (2000). Associative components of recognition memory. *Current Opinion in Neurobiology, 10*, 200-204.

Houston-Price, C., & Nakai, S. (2004). Distinguishing novelty and familiarity effects in infant preference procedures. *Infant and Child Development, 13*, 341-348.

Huang, C.-T., & Charman, T. (2005). Gradations of emulation in infants' imitation of actions on objects. *Journal of Experimental Child Psychology, 92*, 276-302.

Huang, C.-T., Heyes, C., & Charman, T. (2002). Infants' Behavioural Reenactment of "Failed Attempts": Exploring the Roles of Emulation Learning, Stimulus Enhancement, and Understanding of Intentions. *Developmental Psychology, 38*, 840-855.

Hunter, M. A., & Ames, E. W. (1988). A multifactor model of infant preferences for novel and familiar stimuli. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in Infancy Research* (Vol. 5, pp. 69-95). Norwood, N.J.: Ablex

Hunter, M. A., Ross, H. S., & Ames, E. W. (1982). Preferences for familiar or novel toys: Effects of familiarisation time in 1-year-olds. . *Developmental Psychology, 18*, 519-529.

Huttenlocher, P. R. (1994). Synaptogenesis, synapse elimination, and neural plasticity in human cerebral cortex. In C. A. Nelson (Ed.), *Threats to optimal development: Integrating biological, psychological and social risk factors* (Vol. 27, pp. 35-54). New Jersey: Lawrence Erlbaum Associates.

Huttenlocher, P. R., & Dabholkar, A. S. (1997). Regional differences in synaptogenesis in human cerebral cortex. *The Journal of Comparative Neurology, 387*, 168-178.

Iacoboni, M., Woods, R. P., Brass, M., Bekkering, H., Mazziotta, J. C., & Rizzolatti, G. (1999). Cortical Mechanisms of Human Imitation, *Science*, 2526-2528).

Isarida, T., & Isarida, T. (2004). Effects of environmental context manipulated by the combination of place and task on free recall. *Memory, 12*, 376-384.

Jacobs, S. E. (2000). Visual recognition memory for objects in six- and nine-month- old infants. *Occupational Therapy Journal of Research, 20*, 271-285.

Jacoby, L. L. (1991). A process-dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language, 30*, 513-541.

Jaeger, T., Mecklinger, A., & Kipp, K. H. (2006). Intra- and inter-item associations doubly dissociate the electrophysiological correlates of familiarity and recollection. *Neuron, 52*(3), 535-545.

Johnson, R. J. (1995). Event-related potential insights into the neurobiology of memory systems. In F. Boller & J. Grafman (Eds.), *Handbook of Neuropsychology* (Vol. 10, pp. 135-163). Amsterdam: Elsevier.

Jones, E. J. H., & Herbert, J. (2006). Exploring memory in infancy: Deferred imitation and the development of declarative memory. *Infant and Child Development, 15*, 195-205.

Jurica, P. J., & Shimamura, A. P. (1999). Monitoring item and source information: Evidence for a negative generation effect in source memory. *Memory & Cognition, 27*, 648-656.

Kisilevsky, B. S., Hains, S., Lee, K., Xie, X., Huang, H., Ye, H., et al. (2003). Effects of experience on fetal voice recognition. *Psychological Science, 14, 220-224.*

Klein, P., & Meltzoff, A. N. (1999). Long-term memory, forgetting and deferred imitation in 12-month-old infants. *Developmental Science, 2*, 102-113.

Knopf, M., Kraus, U., & Kressley-Mba, R. A. (2006). Relational information processing of novel unrelated actions by infants. *Infant Behavior & Development, 29*, 44-53.

Koski, L., Iacoboni, M., Dubeau, M., Woods, R. P., & Mazziotta, J. (2003). Modulation of cortical activitiy during different imitative behaviours. *Journal of Neurophysiology, 89*, 460-471.

Koski, L., Wohlschlager, A., Bekkering, H., Woods, R. P., Dubeau, M., & Mazziotta, J. (2002). Modulation of motor and premotor activity during imitation of target-directed actions. *Cerebral Cortex, 12*, 847-855.

Kretschmann, H. J., Kammradt, G., Krauthausen, I., Sauer, B., & Wingert, F. (1986). Brain growth in man. *Bibliotheca Anatomica, 28*, 1-26.

Land, C., & Riccio, D. C. (1998). Nonmonotonic Changes in the Context Shift Effect over Time. *Learning and Motivation, 29*, 280-287.

Land, C., & Riccio, D. C. (1999). D-Cycloserine: Effcts on Long-term-retention of a conditioned response and on memory for contexual attributes. *Neurobiology of Learning and Memory, 72*, 158-168.

Lasky, R. E. (1980). Length of familiarization and preference for novel and familiar stimuli. *Infant Behavior and Development, 3*, 15-28.

Learmonth, A. E., Lamberth, R., & Rovee-Collier, C. (2004). Generalization of deferred imitation during the first year of life. *Journal of Experimental Child Psychology, 88*, 297-318.

Learmonth, A., Lamberth, R., & Rovee-Collier, C. (2005). The social context of imitation in infancy. *Journal of Experimental Child Psychology,* 91, 297-314.

Lechuga, M. T., Marcos-Ruiz, R., & Bauer, P. J. (2001). Episodic recall of specifics and generalisation coexist in 25- month-old children. *Memory, 9*, 117-132.

Lehmann, H., Carfagnini, A., Yamin, S., & Mumby, D. G. (2005). Context-dependent effects of hippocampal damage on memory in the shock-probe test. *Hippocampus, 15*, 18-25.

Lew, A. R., Bremner, J. G., & Lefkovitch, L. P. (2000). The development of relational landmark use in 6-12-month-old infants in a spatial orientation task. *Child Development, 71*, 1179-1190.

Macken, W. (2002). Environmental Context and Recognition: the role of recollection and familiarity. *Journal of Experimental Psychology, 28*, 153-161.

MacKenzie, G., & Donaldson, D. I. (2006). Dissociating recollection from familiarity: Electrophysiological evidence that familiarity for faces is associated with a posterior old/new effect. *Neuroimage, 36*, 454-463.

Malcuit, G., Pomerlau, A., & Lamarre, G. (1988). Habituation, visual fixation and cognitive activity in infants: A critical analysis and attempt at a new formulation. *Cahiers de Psychologie Cognitive, 8*, 415-440.

Malmberg, K. J., & Shiffrin, R. M. (2005). The "one-shot" hypothesis for context storage. *Journal of Experimental Psychology, 31*, 322-336.

Mandler, J. M. (1980). Recognising: The judgement of previous occurrence. *Psychological Review, 87*, 252-271.

Mandler, J. M. (1990). Recall of events by preverbal children. In A. Diamond (Ed.), *The development and neural bases of higher cognitive functions* (Vol. 608, pp. 485-503). New York: New York Academy of Sciences.

Mandler, J. M., & McDonough, L. (1995). Long-Term Recall of Event Sequences in Infancy. *Journal of Experimental Child Psychology, 59*, 457-474.

Manns, J. R., Stark, C. E. L., & Squire, L. (2000). The visual paired-comparison task as a measure of declarative memory. *Proceedings of the National Academy of Sciences, 97*, 12375-12379.

Maren, S., Anagnostaras, A. G., & Fanselow, M. S. (1998). The startle seahorse: is the hippocampus necessary for contextual fear conditioning? *Trends in Cognitive Sciences, 2*, 39-42.

Masuda, T., & Nisbett, R. E. (2001). Attending holistically versus analytically: Comparing the context sensitivity of Japanese and Americans. *Personality Processes and Individual Differences, 81*, 922-934.

Masuda, T., & Nisbett, R. E. (2006). Culture and change blindness. *Cognitive Sciences, 30*, 381-399.

McClelland, J. L., McNaughton, B. L., & O'Reilly, R. C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review, 102*, 419-457.

McDonald, R. J., Murphy, R. A., Guarraci, F. A., Gortler, J. R., White, N. M., & Baker, A. G. (1997). Systematic Comparison of the Effects of Hippocampal and Fornix-Fimbria Lesions on Acquisition of Three Configural Discriminations. *Hippocampus, 7*, 371-388.

McDonough, L., Mandler, J. M., McKee, R. D., & Squire, L. R. (1995). The Deferred Imitation Task as a Nonverbal Measure of Declarative Memory. *Proceedings of the National Academy of Sciences of the United States of America, 92*, 7580-7584.

McKee, R. D., & Squire, L. R. (1993). On the Development of Declarative Memory. *Journal of Experimental Psychology-Learning Memory and Cognition, 19*, 397-404.

McKenzie, W. A., & Tiberghien, G. (2004). Context effects in recognition memory: The role of familiarity and recollection. *Consciousness and Cognition, 13*, 20-38.

Mecklinger, A. (2000). Interfacing mind and brain: a neurocognitive model of recognition memory. *Psychophysiology, 37*, 565-582.

Medin, D. L., Reynolds, T. J., & Parkinson, J. (1980). Stimulus similarity and retroactive interference and facilitation in monkey short-term memory. *Journal of Experimental Psychology: Animal Behaviour Processes, 6*, 112-125.

Melik, E., Babar, E., Ozen, E., & Ozgunen, T. (2006). Hypofunction of the dorsal hippocampal NMDA receptors impairs retrieval of memory to partially presented foreground context in a single-trial fear conditioning in rats. *European Neuropsychopharmacology, 16*, 241-247.

Meltzoff, A. N. (1985). Immediate and Deferred Imitation in 14-Month-Old and 24-Month-Old Infants. *Child Development, 56*, 62-72.

Meltzoff, A. N. (1988a). Infant Imitation after a 1-week delay: Long-term memory for Novel Acts and Multiple Stimuli. *Developmental Psychology, 24*, 470-476.

Meltzoff, A. N. (1988b). Infant imitation and memory: Nine-month-olds in immediate and deferred tests. *Child Development, 59*, 217-225

Meltzoff, A. N. (1990a). The implications of cross-modal matching and imitation for the development of representation and memory in infants. In A. Diamond (Ed.), *The Development and Neural Bases of Higher Cognitive Functions* (pp. 1-31). New York: New York Academy of Sciences.

Meltzoff, A. N. (1995). What infant memory tells us about infantile amnesia: Long-term recall and deferred imitation. *Journal of Experimental Child Psychology, 59*, 497-515.

Meltzoff, A. N., & Moore, M. K. (1983). Newborn infants imitate adult facial gestures. *Child Development, 54*, 702-709.

Meltzoff, A. N., & Moore, M. K. (1989). Imitation in newborn infants: Exploring the range of gestures imitated and the underlying mechanisms. *Developmental Psychology, 25*, 954-962.

Merriman, J., Rovee-Collier, C., & Wilk, A. (1997). Exemplar spacing and infants' memory for category information. *Infant Behavior & Development, 20*, 219-232.

Millin, P. M., & Riccio, D. C. (2004). Is the context shift effect a case of retrieval failure? The effects of retrieval enhancing treatments on forgetting under altered stimulus conditions in rats. *Journal of Experimental Psychology-Animal Behavior Processes, 30*, 325-334.

Moore, M. K., & Meltzoff, A. N. (2004). Object Permanence after a 24-hour delay and leaving the locale of disappearance: The role of memory, space and identity. *Developmental Psychology, 40*, 606-620.

Morgan, K., & Hayne, H. (2006). The effect of encoding time on retention by infants and young children. *Infant Behavior & Development, 29*, 599-602.

Mori, M., & Graf, P. (1996). Nonverbal Local Context Cues Explicit but Not Implicit Memory. *Consciousness and Cognition, 5*, 91-116.

Moses, S. N., Cole, C., Driscoll, I., & Ryan, J. D. (2005). Differential contributions of hippocampus, amygdala and perirhinal cortex to recognition of novel objects, contextual stimuli and stimulus relationship. *Brain Research Bulletin, 67*, 62-76.

Moses, S. N., & Ryan, J. D. (2006). A comparison and evaluation of the predictions of relational and conjunctive accounts of hippocampal function. *Hippocampus, 16*, 43-65.

Mulligan, N. W. (2004). Generation and memory for contextual details. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 30*, 838-855.

Mulligan, N. W., Lozito, J. P., & Rosner, Z. A. (2006). Generation and Context Memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*, 836-846.

Mumby, D. G., Gaskin, S., Glenn, M. J., Schramek, T. E., & Lehmann, H. (2002). Hippocampal damage and Exploratory preferences in rats: Memory for Objects, Places and Contexts. *Learning & Memory, 9*, 49-57.

Munakata, Y., & O'Reilly, R. C. (2003). Developmental and Computational Neuroscience Approaches to Cognition: The Case of Generalisation. *Cognitive Studies, 10*, 76-92.

Murnane, K., & Phelps, M. P. (1993). A Global Activation Approach to the Effect of Changes in Environmental Context on Recognition. *Journal of Experimental Psychology-Learning Memory and Cognition, 19*, 882-894.

Murnane, K., & Phelps, M. P. (1994). When Does a Different Environmental Context Make a Difference in Recognition - a Global Activation Model. *Memory & Cognition, 22*, 584-590.

Murnane, K., & Phelps, M. P. (1995). Effects of Changes in Relative Cue Strength on Context-Dependent Recognition. *Journal of Experimental Psychology-Learning Memory and Cognition, 21*, 158-172.

Murnane, K., Phelps, M. P., & Malmberg, K. (1999). Context-dependent recognition memory: The ICE theory. *Journal of Experimental Psychology-General, 128*, 403-415.

Murray, E. A., & Wise, S. P. (2004). What, if anything, is the medial temporal lobe, and how can the amygdala be part of it if there is no such thing? *Neurobiology of Learning and Memory, 82*, 178-198.

Muzzio, I. A., & RoveeCollier, C. (1996). Timing effects of postevent information on infant memory. *Journal of Experimental Child Psychology, 63*, 212-238.

Nadel, L., Willner, J., & Kurz, E. M. (1985). Cognitive Maps and Environmental Context. In P. D. Balsam & A. T. Tomie (Eds.), *Context and Learning* (pp385-406). Hillsdale, N.J.: Lawrence Erlbaum.

Nadel, L., & Zola-Morgan, S. M. (1984). Infantile amnesia: a neurobiological perspective. In M. Moscovitch (Ed.), *Infant Memory* (Vol. 9, pp. 145-172). New York: Plenum Publishing Corporation.

Nagy, E., & Molnar, P. (2004). Homo imitans or homo provocans? Human imprinting model of neonatal imitation. *Infant Behavior & Development, 27*, 54-63.

Nelson, C. A. (1994). Neural correlates of recognition memory in the first postnatal year of life. In G. Dawson & K. Fischer (Eds.), *Human Behavioural and the Developing Brain* (pp. 269-313). New York: Guildford press.

Nelson, C. A. (1995). The ontogeny of human memory: a cognitive neuroscience perspective. *Developmental Psychology, 31*, 723-738.

Nelson, C. A. (1999). Change and Continuity in Neurobehavioural Development: Lessons from the Study of Neurobiology and Neural Plasticity. *Infant Behavior & Development, 22*, 415-429.

Nelson, C. A. (2000). Neural Plasticity and human development: the role of early experience in sculpting early memory systems. *Developmental Science, 3*, 115-136.

Nelson, C. A., & Monk, C. S. (2001). The Use of Event-Related Potentials in the Study of Cognitive Development. In C. A. Nelson & M. Luciana (Eds.), *Handbook of Developmental Cognitive Neuroscience* (pp. 125-136). Cambridge, MA: MIT Press.

Nelson, C. A., Thomas, K. M., de Haan, M., & Wewerka, S. (1998). Delayed recognition memory in infants and adults as revealed by event-related potentials. *International Journal of Psychophysiology, 29*, 145-165.

Nemanic, S., Alvarado, M. C., & Bachevalier, J. (2004). The Hippocampal/Parahippocampal Regions and Recognition Memory: Insights from Visual Paired Comparison versus Object-Delayed Nonmatching in Monkeys. *Journal of Neuroscience, 24*, 2013-2026.

Nessler, D., & Mecklinger, A. (2003). ERP correlates of true and false recognition after different retention delays: stimulus and response-related processes. *Psychophysiology, 40*, 146-159.

Nessler, D., Mecklinger, A., & Penney, T. B. (2001). Event-related brain potentials and illusory memories: the effects of differential encoding. *Cognitive Brain Research, 10*, 283-301.

Niedermeyer, E., & da Silva, F. (2005). *Electroencephalography: Basic principles, clinical applications and related fields*: Lippincott, Williams and Wilkins.

Nisbett, R.E. (2003). *The geography of thought: How Asians and Westerners think differently.. and why.* Free Press, New York.

Nishitani, N., & Hari, R. (2000). Temporal dynamics of cortical representation for action *Proceedings of the National Academy of Sciences, 97*, 913-918.

Norman, K. A., & O'Reilly, R. C. (2003). Modelling hippocampal and neocortical contributions to recognition memory: A complementary-learning-systems approach. *Psychological Review, 110*(4), 611-646.

Nunez PL (2002) EEG. In VS Ramachandran (Ed) Encyclopedia of the Human Brain, La Jolla: Academic Press, 169-179.

O'Brien, N., Lehmann, H., Lecluse, V., & Mumby, D. G. (2006). Enhanced context-dependency of object recognition in rats with hippocampal lesions. *Behavioural Brain Research, 170*, 156-162.

Ofen, N., Kao, Y.-C., Sokol-Hessner, P., Kim, H., Whitfield-Gabrieli, S., & Gabrieli, J. D. E. (2007). Development of the declarative memory system in the human brain. *Nature Reviews Neuroscience*, 1-8.

O'Keefe, J., & Nadel, L. (1978). *The hippocampus as a cognitive map*. Oxford: Oxford University Press.

Olichney, J. M., Van Petten, C., Paller, K. A., Salmon, D. P., Iragui, V. J., & Kutas, M. (2000). Word repetition in amnesia: electrophysiological measures of impaired and spared memory. *Brain, 123*, 1948-1963.

Olson, I. R., Chun, M. M., & Allison, T. (2001). Contextual guidance of attention - Human intracranial event- related potential evidence for feedback modulation in anatomically early, temporally late stages of visual processing. *Brain, 124*, 1417-1425.

Olson, G. M., & Sherman, T. (1983). Attention, learning and memory in infants. In M. Haith & J. J. Campos (Eds.), *Handbook of child psychology: Vol. 2. Infancy and the biology of development* (pp. 1001-1080). New York: Wiley.

Opitz, B., & Cornell, S. (2006). Contribution of familiarity and recollection to associative recognition memory: Insights from event-related potentials. *Journal of Cognitive Neuroscience, 18*, 1595-1605.

O'Reilly, R. C. (2001). Generalisation in interactive networks: The benefits of inhibitory competition and Hebbian learning. *Neural Computation, 13*, 1199-1242.

O'Reilly, R. C., & McClelland, J. L. (1994). Hippocampal conjunctive encoding, storage and recall: Avoiding a trade-off. *Hippocampus, 4*, 661-682.

O'Reilly, R. C., & Rudy, J. W. (2001). Conjunctive Representations in Learning and Memory: Principles of Cortical and Hippocampal Function. *Psychological Review, 108*, 311-345.

Overton, D. A. (1985). Contextual Stimulus Effects of Drugs and Internal States. In P. D. Balsam & A. T. Tomie (Eds.), *Context and Learning* (pp. 357-385). Hillsdale, N.J.: Lawrence Erlbaum.

Pancratz, C. N., & Cohen, L. H. (1970). Recovery of habituation in infants. *Journal of Experimental Child Psychology, 9*, 208-216.

Pascalis, O., & Bachevalier, J. (1999). Neonatal aspiration lesions of the hippocampal formation impair visual recognition memory when assessed by paired-comparison task but not by delayed nonmatching-to-sample task. *Hippocampus, 9*, 609-616.

Pascalis, O., & de Haan, M. (2001). Recognition memory and novelty preference: What model? In H. Hayne & J. Fagan (Eds.), *Progress in Infancy Research* (Vol. 3, pp. 95-119). Hillsdale, NJ: Lawrence Erlbaum Associates.

Pascalis, O., de Haan, M., Nelson, C. A., & de Schonen, S. (1998). Long-Term Recognition Memory for Faces Assessed by Visual Paired Comparison in 3- and 6-Month-Old Infants. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 24*, 249-260.

Pascalis, O., & De Schonen, S. (1994). Recognition memory in 3- to 4-day-old human neonates. *NeuroReport, 5*, 1721-1724.

Pascalis, O., De Schonen, S., Morton, J., Dereulle, C., & Fabre-Grenet, M. (1995). Mother's face recognition by neonates: A replication and extension. *Infant Behavior & Development, 1*, 79-85.

Pascalis, O., Hunkin, N. M., Holdstock, J. S., Isaac, C. L., & Mayes, A. R. (2004). Visual Paired Comparison performance is impaired in a patient with selective hippocampal lesions and relatively intact item recognition. *Neuropsychologia, 42*, 1293-1300.

Perfect, T. J., Mayes, A. R., Downes, J. J., & Van Eijk, R. (1996). Does context discriminate recollection from familiarity in recognition memory? *Quarterly Journal of Experimental Psychology Section A-Human Experimental Psychology, 49*, 797-813.

Pescara-Kovach, L., Fulkerson, A. L., & Haaf, R. A. (2000). Do you hear what I hear? Auditory context, attention and recognition in six-month-old infants. *Infant Behavior & Development, 23*, 119-123.

Petry, C. D., Eaton, M. A., Wobken, J. D., Mills, M. M., Johnson, D. E., & Georgieff, M. K. (1992). Iron deficiency of liver, heart, and brain in newborn infants of diabetic mothers. *Journal of Pediatrics, 121*, 109-114.

Pfluger, T., Weil, S., Weis, S., Vollmar, C., Heiss, D., Egger, J., Scheck, R. & Kahn, K. (1999). Normative volumetric data of the developing hippocampus in children based on magnetic resonance imaging. *Epilepsia, 40*, 414-423.

Pfungst, O. (1965). *Clever Hans.* University of Michigan: Holt, Rinehart & Winston.

Piaget, J. (1962). *Play, dreams and imitation in childhood.* London: Routledge and Kegan Paul.

Piatt, Curran, Collins, and Woroch (unpublished data). Reported in Curran, T., Tepe, K. L., & Piatt, C. (2006). Event-related potential explorations of dual processes in recognition memory. In H. D. Zimmer, A. Mecklinger & U. Lindenberger (Eds.), *Binding in Human Memory: A Neurocognitive Approach* (pp. 467-492). Oxford: Oxford University Press.

Picton, T. W., Bentin, S., Berg, P., Donchin, E., Hillyard, S. A., Johnson, J. R. R., et al. (2000). Guidelines for using human event-related potentials to study cognition: Recording standards and publication criteria. *Psychophysiology, 37*, 127-152.

Porter, R. H., Balogh, R. D., & Makin, J. W. (1988). Olfactory influences on mother-infant interactions. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in Infancy Research* (Vol. 5, pp. 39-68). Norwood, N.J.: Ablex.

Prudhomme, N. (2005). Early declarative memory and self-concept. *Infant Behavior & Development*, *28*, 132-144.

Rafman, S. (1974). The infant's reaction to imitation of the mother's behaviour by the stranger. In T. Decarie (Ed.), *The infant's reaction to strangers*. New York: International Universities Press.

Ranganath, C., Yonelinas, A. P., Cohen, M. X., Dy, C. J., Tom, S. M., & D'Esposito, M. (2003). Dissociable correlates of recollection and familiarity within the medial temporal lobes. *Neuropsychologia, 42*, 2-13.

Reber, A. S. (1995). *Dictionary of Psychology*. London, England: Penguin.

Reder, L. M., Oates, J. M., Thornton, E., Quinlan, J., Kaufer, A., & Sauer, J. (2006). Drug-Induced Amnesia hurts recognition, but only for memories that can be unitised. *Psychological Science, 17*, 562-567.

Rheingold, H., & Eckerman, C. (1973). Fear of the stranger: a critical examination. In H. Rheese (Ed.), *Advances in Child Development and Behaviour*. New York: Academic Press.

Riccio, D. C., Richardson, R., & Ebner, D. (1999). The contextual change paradox is still unresolved: comment on Bouton, Nelson, and Rosas (1999). *Psychological Bulletin, 125*, 188-190.

Richards, J. E. (1997). Effects of attention on infants' preference for briefly exposed visual stimuli in the paired-comparison recognition-memory paradigm. *Developmental Psychology, 33*, 22-31.

Richardson, R., Riccio, D. C., & Axiotis, R. (1986). Alleviation of infantile amnesia in rats by internal and external contextual cues. *Developmental Psychobiology, 19*, 453-462.

Richardson, R., Riccio, D. C., and Jonke, T. (1983). Alleviation of infantile amnesia in rats by means of a pharmacological contextual state. *Developmental. Psychobiology*, *16,* 511-518.

Richardson, R., Riccio, D. C., & McKenney, M. (1988). Stimulus Attributes of Reactivated Memory: Alleviation of Ontogenetic Forgetting in Rats is Context Specific. *Developmental Psychobiology, 21*, 135-143.

Richmond, J., & Nelson, C. A. (2007). Accounting for change in declarative memory: A cognitive neuroscience perspective. *Developmental Review, in press*.

Richmond, J., Sowerby, P., Colombo, M., & Hayne, H. (2004). The effect of familiarization time, retention interval, and context change on adults' performance in the visual paired- comparison task. *Developmental Psychobiology, 44*, 146-155.

Robinson, A., & Pascalis, O. (2004). Development of flexible visual recognition memory in human infants. *Developmental Science, 7*, 527.

Rosas, J. M., & Bouton, M. (1997). Additivity of the effects of retention interval and context change on latent inhibition: Towards resolution of the context forgetting paradox. *Journal of Experimental Psychology-Animal Behavior Processes, 23*, 283-294.

Rose, S. A. (1981). Developmental changes in infants' retention of visual stimuli. *Child Development, 52*, 227-233.

Rose, S. A. (1983). Differential rates of visual information processing in full-term and preterm infants. *Child Development, 54*, 1189-1198.

Rose, S.A. and Feldman, J.F., (1990). Infant cognition: Individual differences and developmental continuities. In: Colombo, J. and Fagen, J., Editors, 1990. *Individual differences in infancy: Reliability, stability, prediction*, Erlbaum, Hillsdale, NJ, pp. 229–245.

Rose, S. A., & Feldman, A. (1995). Prediction of IQ and Specific Cognitive Abilities at 11 Years From Infancy Measures. *Developmental Psychology, 31*, 685-696.

Rose, S. A., Feldman, A., & Jankowski, J. J. (2001). Visual Short-Term Memory in the First Year of Life: Capacity and Recency Effects. *Developmental Psychology, 37*, 539-549.

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2004). Infant visual recognition memory. *Developmental Review, 24*, 74-100.

Rose, S. A., Feldman, J. F., & Wallace, I. F. (1992). Infant Information Processing in Relation to Six-Year Cognitive Outcomes. *Child Development, 63*, 1126-1141.

Rose, S. A., Gottfried, A. W., Melloy-Carminar, P. M., & Bridger, W. H. (1982). Familiarity and novelty preferences in infant recognition memory. *Developmental Psychology, 18*, 704-713.

Rossi-George, A., & Rovee-Collier, C. (1999). Retroactive interference in 3-month-old infants. *Developmental Psychobiology, 35*, 167-177.

Ross-Sheehy, S., Oakes, L. M., & Luck, S. J. (2003). The development of visual short term memory capacity in infants. *Child Development, 74*, 1807-1822.

Rothkopf, E. Z., Fisher, D. G., & Billington, M. J. (1982). Effects of spatial context during acquisition on the recall of attributive information. *Journal of Experimental Psychology-Learning Memory and Cognition, 8*, 126-138.

Rougier, N. P., Noelle, D., Braver, T. S., Cohen, J. D., & O'Reilly, R. C. (2005). Prefrontal cortex and flexible cognitive control: rules without symbols. *Proceedings of the National Academy of Sciences, 102*, 7338-7343.

Rovee, C. K., & Fagen, J. W. (1976). Extended Conditioning and 24-Hour Retention in Infants. *Journal of Experimental Child Psychology, 21*, 1-11.

Rovee-Collier, C. (1996). Shifting the focus from what to why. *Infant Behavior & Development, 19*, 385-400.

Rovee-Collier, C. (2001). Information pick-up by infants: What is it, and how can we tell? *Journal of Experimental Child Psychology, 78*, 35-49.

Rovee-Collier, C., Adler, S. A., & Borza, M. A. (1994). Substituting New Details for Old - Effects of Delaying Postevent Information on Infant Memory. *Memory & Cognition, 22*, 644-656.

Rovee-Collier, C., Borza, M. A., Adler, S. A., & Boller, K. (1993). Infants Eyewitness Testimony - Effects of Postevent Information on a Prior Memory Representation. *Memory & Cognition, 21*, 267-279.

Rovee-Collier, C., & Dufault, D. (1991). Multiple Contexts and Memory Retrieval at 3 Months. *Developmental Psychobiology, 24*, 39-49.

Rovee-Collier, C., & Hayne, H. (1987). Reactivation of Infant Memory - Implications for Cognitive-Development. *Advances in Child Development and Behavior, 20*, 185-238.

Rovee-Collier, C. K., & Sullivan, M. W. (1980). Organization of Infant Memory. *Journal of Experimental Psychology-Human Learning and Memory, 6*, 798-807.

Rovee-Collier, C., Griesler, P. C., & Earley, L. A. (1985). Contextual Determinants of Retrieval in 3-Month-Old Infants. *Learning and Motivation, 16*, 139-157.

Rovee-Collier, C., Hayne, H., & Colombo, M. (2001). *The development of implicit and explicit memory* (Vol. 24). Amsterdam, Netherlands: John Benjamin Publishing Company.

Rovee-Collier, C., Schechter, A., Shyi, G. C. W., & Shields, P. (1992). Perceptual Identification of Contextual Attributes and Infant Memory Retrieval. *Developmental Psychology, 28*, 307-318.

Rubin, G. B., Fagen, J. W., & Carroll, M. H. (1998). Olfactory context and memory retrieval in 3-month-old infants. *Infant Behavior & Development, 21*, 641-658.

Rudy, J. W. (1994). Ontogeny of Context-Specific Latent Inhibition of Conditioned Fear - Implications for Configural Associations Theory and Hippocampal-Formation Development. *Developmental Psychobiology, 27*, 367-379.

Rudy, J. W., & Morledge, P. (1994). Ontogeny of contextual fear conditioning in rats: Implications for consolidation, infantile amnesia, and hippocampal system functioning. *Behavioral Neuroscience, 108*, 227-234.

Rudy, J. W., & O'Reilly, R. C. (1999). Contextual fear conditioning, conjunctive representations, pattern completion and the hippocampus. *Behavioural Neuroscience, 113*, 867-880.

Rudy, J. W., & O'Reilly, R. C. (2001). Conjunctive representations, the hippocampus, and contextual fear conditioning. *Cognitive, Affective and Behavioural Neuroscience, 1*, 66-82.

Rudy, J. W., Barrientos, R. M., & O'Reilly, R. C. (2002). Hippocampal formation supports conditioning to memory of a context. *Behavioral Neuroscience, 116*, 530-538.

Rudy, J. W., Huff, N. C., & Matus-Anat, P. (2004). Understanding contextual fear conditioning: insights from a two-process model. *Neuroscience and Behavioural Reviews*, 1-11.

Rugg, M. D. (1995). ERP studies of memory. In M. D. Rugg & M. G. H. Coles (Eds.), *Electrophysiology of mind* (pp. 132-170). New York: Oxford University Press.

Rugg, M. D., & Coles, M. G. H. (1995). *Electrophysiology of Mind.* New York: Oxford University Press.

Rugg, M. D., & Curran, T. (2007). Event-related potentials and recognition memory. *Trends in Cognitive Sciences, 111*, 251-257.

Rugg, M. D., Mark, R. E., Walla, P., Schloerscheidt, A. M., Birch, C. S., & Allan, K. (1998). Dissociation of the neural correlates of implicit and explicit memory. *Nature, 392*, 595-598.

Rugg, M. D., & Nagy, E. (1989). Event-related potentials and recognition memory for words. *Electroencephalography and Clinical Neurophysiology, 72*, 395-406.

Rugg, M. D., & Yonelinas, A. P. (2003). Human recognition memory: a cognitive neuroscience perspective. *Trends in Cognitive Sciences, 7*, 313-319.

Rugg, M. D., Otten, L. J., & Henson, R. (2002). The neural basis of episodic memory: Evidence from functional neuroimaging. *Philosophical Transactions of the Royal Society of London Series B, 257*, 1097-1110.

Russo, R., Ward, G., Geurts, H., & Scheres, A. (1999). When unfamiliarity matters: Changing environmental context between study and test affects recognition memory for unfamiliar stimuli. *Journal of Experimental Psychology-Learning Memory and Cognition, 25*, 488-499.

Rutherford, A. (2004). Environmental context-dependent recognition memory effects: An examination of ICE model and cue-overload hypotheses. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 57*, 107-127.

Ryan, J. D., & Cohen, N. J. (2004). Processing and short-term retention of relational information in amnesia. *Neuropsychologia, 42*, 497-511.

Ryan, J. D., Althoff, R. R., Whitlow, S., & Cohen, N. J. (2000). Amnesia is a deficit in relational memory. *Psychological Science, 11*, 454-461.

Scachter, D. L., & Graf, P. (1986). Effects of elaborative processing on implicit and explicit memory for new associations. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 12*, 432-444.

Scachter, D. L., Harbluk, J. L., & McLachlan, D. R. (1984). Retrieval without recollection: an experimental analysis of source amnesia. *Journal of Verbal Learning and Verbal Behaviour, 23*, 593-611.

Schacter, D. L., & Moscovitch, M. (1984). Infants, amnesics and dissociable memory systems. In M. Moscovitch (Ed.), *Infant memory* (pp. 173-216). New York: Plenum.

Schloerscheidt, A. M., & Rugg, M. D. (2004). The impact of change in stimulus format on the electrophysiological indices of recognition. *Neuropsychologia, 42*, 451-466.

Schroers, M., Prigot, J., & Fagen, J. (2007). The effect of a salient odor context on memory retrieval in young infants. *Infant Behavior and Development, In Press, Corrected Proof.*

Scoville, W. B., & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. *Journal of Neurology, Neurosurgery and Psychiatry, 20*, 11-12.

Seress, L. (2001). Morphological changes of the human hippocampal formation from midgestation to early childhood. In C. A. Nelson & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience* (pp. 45-58). Cambridge, M.A.: MIT Press.

Seress, L., Abraham, H., Tornoczky, T., & Kosztolanyi, G. (2001). Cell formation in the human hippocampal formation from mid-gestation to the late postnatal period. *Neuroscience, 105*, 831-843.

Shields, P. J., & Rovee-Collier, C. (1992). Long-Term-Memory for Context-Specific Category Information at 6 Months. *Child Development, 63*, 245-259.

Simons, J., & Spiers, H. (2003). Prefrontal and medial temporal lobe interactions in long-term memory. *Nature Reviews Neuroscience, 4*, 637-648.

Skinner, E. I., & Fernandes, M. A. (2007). Neural correlates of recollection and familiarity: A review of neuroimaging and patient data. *Neuropsychologia, 45*, 2163-2179.

Slater, A. (1995). Visual perception and memory at birth. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in Infancy Research* (Vol. 9, pp. 107-162). Norwood, N.J.: Ablex.

Slater, A. (2004). Novelty, familiarity and infant reasoning. Infant and Child Development, 13(4), 353-355.

Slater, A., & Quinn, P. (2001). Face recognition in the newborn infant. *Infant and Child Development, 10*, 21-24.

Slater, A., Morison, V., & Rose, D. (1983). Locus of habituation in the newborn. *Perception 12*, 593-598.

Sluzenski, J., Newcombe, N. S., & Kovacs, S. L. (2006). Binding, Relational Memory, and Recall of Naturalistic Events: A Developmental Perspective. *Journal of Experimental Psychology-Learning Memory and Cognition, 32*, 89-100.

Sluzenski, J., Newcombe, N. S., & Satlow, E. (2004). Knowing where things are in the second year of life: Implications for hippocampal development. *Journal of Cognitive Neuroscience, 16*, 1443-1451.

Smith, S. M. (1982). Enhancement of recall using multiple environmental contexts during learning. *Memory & Cognition, 10*, 405-412.

Smith, S. M. (1985). Environmental Context and Recognition Memory reconsidered. *Bulletin of the Psychonomic Society, 23*, 173-176.

Smith, S. M. (1986). Environmental context-dependent recognition memory using a short-term memory task for input. *Memory & Cognition, 14*, 347-354.

Smith, S. M. (1988). Environmental context-dependent memory. In G. M. Davies & D. M. Thomson (Eds.), *Memory in Context: Context in Memory* (Vol. Chapter 2): John Wiley & Sons Ltd.

Smith, S. M. (1994). Theoretical principles of context-dependent memory. In P. Morris & M. Gruneberg (Eds.), *Theoretical aspects of memory* (2nd ed., Vol. 2, pp. 168-195). New York: Routledge.

Smith, G. J., Glenberg, A. M., & Bjork, R. A. (1978). Environmental context and human memory. *Memory & Cognition, 6*, 342-353.

Smith, A. D., Hood, B. M., & Hector, K. (2006). Eye remember you two: Gaze direction modulates face recognition in a developmental study. Developmental Science, 9, 465-472.

Smith, S. M., & Vela, E. (1992). Environmental Context-Dependent Eyewitness Recognition. *Applied Cognitive Psychology, 6*, 125-139.

Smith, S. M., & Vela, E. (2001). Environmental context-dependent memory: A review and meta-analysis. *Psychonomic Bulletin and Review, 8*(2), 203-220.

Snyder, K. A., Blank, M. P., & Marsolek, C. J. (in press). What form of memory underlies novelty preferences? *Psychonomic Bulletin & Review.*

Solokov, E. N. (1963). Higher nervous functions: The orienting reflex. *Annual Review of Physiology, 25*, 545-580.

Sophian, C. (1980). Habituation is not enough: Novelty preferences, search and memory in infancy. *Merrill-Palmer Quarterly, 26*, 239-257.

Spear, N. E. (1978). *The processing of memories: forgetting and retention.* Hillsdale, NJ: Erlbaum.

Spence, M. J. (1996). Young infants' long-term auditory memory: Evidence for changes in preferences as a function of delay. . *Developmental Psychobiology, 29*, 685-695.

Squire, L.R. (1992). Declarative and nondeclarative memory: Multiple brain systems supporting learning and memory. *Journal of Cognitive Neuroscience, 4*, 232-243.

Squire, L. R. (2004). Memory systems of the brain: A brief history and current perspective. *Neurobiology of Learning and Memory, 82*, 171-177.

Sroufe, L. A. (1977). Wariness of Strangers and the study of infant development. *Child Development, 48*, 731-746.

Streri, A., & Gentaz, E. (2003). Cross-modal recognition of shape from hand to eyes in human newborns. *Somatosensory and motor research, 20*, 13-18.

Streri, A., & Gentaz, E. (2004). Cross-modal recognition of shape from hand to eyes and handedness in human newborns. *Neuropsychologia, 42*, 1365-1369.

Strid, K., Tjus, T., Smith, L., Meltzoff, A. N., & Heimann, M. (2006). Infant recall memory and communication predicts later cognitive development. *Infant Behavior and Development, 29*, 545-553.

Summerfield, C., & Mangels, J. A. (2004). Coherent theta-band EEG activity predicts item-context binding during encoding. *NeuroImage, 24, 692-703.*

Srinivisan R, Nunez PL, Silberstein RB, Tucker DM, Cadusch PJ. (1996). Spatial sampling and filtering of EEG with spline-Laplacians to estimate cortical potentials. *Brain Topography,* 8, 355–366.

Thomas, D. G., Grice, J. W., Najm-Briscoe, R. G., & Miller, J. W. (2004). The influence of unequal numbers of trials on comparisons of average event-related potentials. *Developmental Neuropsychology, 26,* 753-774.

Thompson, D., & Russell, J. R. (2004). The Ghost Condition: Imitation Versus Emulation in Young Children's Observational Learning. *Developmental Psychology, 40, 882-889.*

Tomasello, M. (1990). Cultural transmission in tool use and communicatory signalling of chimpanzees? . In S. Parker & K. Gibson (Eds.), *Comparative developmental psychology of language and intelligence in primates* (pp. 247-311). Cambridge: Cambridge University Press.

Tomasello, M., & Call, J. (1997). *Primate cognition.* Oxford: Oxford University Press.

Tsivilis, D., Otten, L. J., & Rugg, M. D. (2001). Context effects on the neural correlates of recognition memory: an electrophysiological study. *Neuron, 31,* 497-505.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & D. I. Donaldson (Eds.), *Organisation of Memory* (pp. 383-403). New York: Academic Press.

Tulving, E. (1983). *Elements of episodic memory.* New York: Oxford University Press.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychology, 26,* 1-12.

Tulving, E. (2002). Episodic memory: from mind to brain. *Annual Review of Psychology, 53,* 1-25.

Tulving, E., & Thompson, D. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80,* 352-379.

Turati, C., Simion, F., & Zanon, L. (2003). Newborns' Perceptual Categorization for Closed and Open Geometric Forms (Vol. 4, pp. 309-325).

Utsunomiya, H., Takano, K., Okazaki, M., & Mitsudome, A. (1999). Development of the Temporal Lobe in Infants and Children: Analysis by MR-Based Volumetry (Vol. 20, pp. 717-723).

van Hoof, J. C. (2005). The influence of encoding intention on electrophysiological indices of recognition memory. *International Journal of Psychophysiology, 56,* 25-36.

Van Petten, C. (2004). Relationship between hippocampal volume and memory ability in healthy individuals across the lifespan: review and meta-analysis. *Neuropsychologia, 42*, 1394-1413.

Van Petten, C., Kutas, M., Mitchner, M., & McIsaac, H. (1991). Fractionating the word repetition effect with event-related potentials. *Journal of Cognitive Neuroscience, 3*, 131-150.

Vargha-Khadem, F., Gadian, D..G., Watkins, K. E., Connelly, A., Van Paesschen, W., & Mishkin, M. (1997). Differential effects of early hippocampal pathology on episodic and semantic memory. *Science*, 277, 376-380.

Vargha-Khadem, F., Salmond, C. H., Watkins, K. E., Friston, K. J., Gadian, D. G., & Mishkin, M. (2003). Developmental amnesia: effect of age at injury. *Proceedings of the National Academy of Sciences, 100*, 10055-10060.

Vazdarjanova, A., & Guzowski, J. F. (2004). Differences in Hippocampal Neuronal Population Responses to Modifications of an Environmental Context: Evidence for Distinct, Yet Complementary, Functions of CA1 and CA3 ensembles. *The Journal of Neuroscience, 24*, 6489-6496.

Vilberg, K. L., Moosavi, R. F., & Rugg, M. D. (2006). The relationship between electrophysiological correlates of recollection and amount of information retrieved. *Brain Research*, 1122, 161-170.

Voss, J. L., & Paller, K. A. (2007). Neural correlates of conceptual implicit memory and their contamination of putative neural correlates of explicit memory. *Learning & Memory, 14*, 259-267.

Wagner, A. D., Shannon, B. J., Kahn, I., & Buckner, R. L. (2005). Parietal lobe contributions to episodic memory retrieval. *Trends in Cognitive Sciences, 9*, 445-453.

Wagner, S. H., & Sakovitz, L. J. (1986). A process analysis in infant visual and cross-modal recognition memory: Implications for an amodal code. . *Advances in infancy research, 4*, 195-217.

Want, S., & Harris, P. (2002). How do children ape? Applying concepts from the study of nonhuman primates to the developmental study of 'imitation' in children. *Developmental Science, 5*, 1-41.

Waters, E., Matas, L., & Sroue, L. A. (1975). Infants' reactions to an approaching stranger: description, validation, and functional significance of wariness. *Child Development, 46*, 348-356.

Watkins, M. J. (1979). Engrams as cuegrams and forgetting as a cue-overload effect: A cueing approach to the structure of memory. In C. R. Puff (Ed.), *Memory organisation and structure*. New York: Academic Press.

Watkins, O. C., & Watkins, M. J. (1975). Build-up of proactive inhibition as a cue-overload effect. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 104*, 442-453.

Webb, S. J., Monk, C. S., & Nelson, C. A. (2001). Mechanisms of Postnatal Neurobiological Development: Implications for Human Development. *Developmental Neuropsychology, 19*, 147-171.

Wewerka, S., Luciana, M. (1999). Data reported in Nelson, C. A., & Monk, C. S. (2001). The Use of Event-Related Potentials in the Study of Cognitive Development. In C. A. Nelson & M. Luciana (Eds.), *Handbook of Developmental Cognitive Neuroscience* (pp. 125-136). Cambridge, MA: MIT Press.

Whishaw, I. A., & Tomie, J. A. (1991). Acquisition and retention by hippocampal rats of simple, conditional and configural tasks using tactile and olfactory cues: implications for hippocampal functioning. *Behavioral Neuroscience, 195*, 787-797.

White, B. (2004). Retrieved 4.9.2007 from http://pubs.niaaa.nih.gov/publications/arh27-2/186-196.htm

Widness, J. A., Susa, J. B., Garcia, J. F., Singer, O. B., Sehgal, P., Oh, W., Schwartz, R., & Schwartz, H.C. (1981). Increased erythropoiesis and elevated erythropoietin in infants born to diabetic mothers and in hyperinsulinemic rhesus fetuses. *Journal of Clinical Investigation, 67*, 637-642.

Wilding, E., Doyle, M. C., & Rugg, M. D. (1995). Recognition memory with and without retrieval of context: an event-related potential study. *Neuropsychologia, 33*, 743-767.

Wilding, E., & Rugg, M. D. (1996). An event-related potential study of recognition memory with and without retrieval of source. *Brain, 119*, 889-905.

Wilding, E., & Rugg, M. D. (1997). An event-related potential study of recognition memory for words spoken aloud or heard. *Neuropsychologia, 35*, 1185-1195.

Winocour, G., & Kinsbourne, M. (1978). Contextual cuing as an aid to Korsakoff amnesics. *Neuropsychologia, 16*, 671-682.

Winocur, G., & Olds, J. (1978). Effects of Context Manipulation on Memory and Reversal-Learning in Rats with Hippocampal-Lesions. *Journal of Comparative and Physiological Psychology, 92*, 312-321.

Winocur, G. (1997). Hippocampal lesions alter conditioning to conditional and contextual stimuli. *Behavioural Brain Research, 88*, 219-229.

Wixted, J. T. (2007). Dual-process theory and signal-detection theory of recognition memory. *Psychological Review, 114*, 152-176.

Wolk, D. A., Schacter, D. L., Lygizos, M., Sen, N. M., Holcomb, P. J., Daffner, K. R., Budson, A.E. (2006). ERP correlates of recognition memory: Effects of retention interval and false alarms. *Brain Research, 1096*, 148-162.

Woodruff, C. C., Hayama, H. R., & Rugg, M. D. (2006). Electrophysiological dissociation of the neural correlates of recollection and familiarity. *Brain Research, 1100*, 125-135.

Yap, C. S. L., & Richardson, R. (2005). Latent Inhibition in the Developing Rat: An Examination of Context-Specific Effects. *Developmental Pscyhobiology, 47*, 55-65.

Yonelinas, A. P. (1994). Receiver-operating characteristics in recognition memory: Evidence from a dual-process model. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 20*, 1341-1354.

Yonelinas, A. P. (2002). Effects of extensive temporal lobe damage or mild hypoxia on recollection and familiarity *Nature Neuroscience, 5*, 1236-1241.

Yonelinas, A. P., Kroll, N. E., Dobbins, I. G., & Soltani, M. (1999). Recognition memory for faces: when familiarity supports associative recognition. *Psychonomic Bulletin & Review, 6*, 654-661.

Yonelinas, A. P., Otten, L. J., Shaw, L. J., & Rugg, M. D. (2005). Separating the brain regions involved in recollection and familiarity in recognition memory. *Journal of Neuroscience, 25*, 3002-3008.

Young, S. L., Bohenek, D. L., & Fanselow, M. S. (1994). NMDA processes mediate anterograde amnesia of contextual fear conditioning induced by hippocampal damage: Immunisation against amnesia by context pre-exposure. *Behavioural Neuroscience, 108*, 19-29.

Yovel, G., & Paller, K. A. (2004). The neural basis of the butcher-on-the-bus phenomenon: when a face seems familiar but is not remembered. *Neuroimage, 21*, 789-800.

Zhou, Y., & Riccio, D. C. (1994). Pretest cuing can alleviate the forgetting of contextual stimulus attributes. *Learning and Motivation, 25*, 233-244.

Zhou, Y., & Riccio, D. C. (1996). Manipulation of Components of Context: The Context Shift Effect and Forgetting of Stimulus Attributes. *Learning and Motivation, 27*, 400-407.

Zola, S. M., Squire, L. R., Teng, E., Stefanacci, L., Buffalo, E. A., & Clark, R. E. (2000). Impaired recognition memory in monkeys after damage limited to the hippocampal region. *Journal of Neuroscience, 20*, 451-463.