Age of acquisition effects in first and second languages

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Abstract

The aim of the present thesis was to examine the AoA effect on lexical processing of first and second languages. By doing so it was expected to shed some light over aspects of the nature and location of the AoA effect. Chapter One reviews factors affecting the achievement of bilinguality, several proposals of bilingual lexical organization, and two models of bilingual word recognition and production. Also considered are the findings on the AoA influence over a number of lexical tasks and the latest accounts of the AoA effect. Chapter Two consists of an initial testing of the AoA effect on Spanish and English as first languages. Chapter Three goes on to assess the AoA effect on English as a second language. The results of these experiments suggest that the AoA effect found in L2 could be in fact a reflection of the AoA effect of L1. For this reason, Chapter Four examines whether first language AoA effects are independent from second language AoA effects. Chapter Five explores the claim that AoA emerges from arbitrary connections formed between representations. This idea was tested with a word reading task completed in Spanish a language with predictable letter to sound connections, and in English, a language with more arbitrary mappings between letters and sounds. The results of experiments in Chapter Four and Five suggest that AoA is not likely to be located at the semantic representations level. Chapter Six further examines the relation between the AoA effect and the semantic representations on a translation judgement task. Finally, Chapter Seven discusses the results of the present thesis on the light of current theories of AoA and models of bilingual lexical organisation.

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I dedicate this thesis to my mum who was and is an angel.

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CHAPTER ONE

AGE OF ACQUISITION EFFECTS IN LEXICAL PROCESSING.

1.1 Introduction

The cognitive mechanisms that underlie the use of language are one of the main interests in psycholinguistic research. Through the study of brain damaged individuals, children's language development, adult lexical performance, and computer simulations, a great understanding of the language system has already been gained. Another area of interest in cognitive research is that of bilingualism. The study of bilingualism has not only helped to understand how bilinguals process two languages and how these languages are stored, it has also provided valuable insights on general cognitive and linguistic processes.

One line of research frequently utilised in the investigation of monolingual and bilingual lexical processing is the comparison of reaction times (RTs) and/or accuracy across different tasks or across different sets of stimuli within the same task. Picture naming, lexical decision and word naming belong to a group of basic tasks traditionally used in the investigation of the lexicon. They capture elemental lexical processes such as word production and word recognition, providing evidence crucial to the construction of theories and models of language organisation. Within these models there is general agreement on the basic cognitive modules involved in the comprehension and production of single words, such as semantic and lexical modules. However, how exactly the specific components of each module such as object representations, concepts, and words are stored and related to each other is still a matter of debate.

Words differ in the central components of language; orthography, phonology, morphology, semantics and syntax. In addition, the use and configuration of any language endows words with other types of attributes such as their frequency of use, their degree of concreteness etc. The study of how different properties of the words affect lexical processing latencies has proved to be a useful tool in the investigation of lexical organization and cognitive processes in monolinguals and bilinguals. The frequency at which a word is encountered is possibly the lexical attribute most extensively studied. Its effect has been widely investigated and it has been considered the key factor in explaining how words are accessed for recognition and production. As a consequence it has been incorporated in a number of models of monolingual and bilingual lexical processing (McClelland & Rumelhart, 1981; Dijkstra & Van Heuven, 1998).

However, word frequency is not the only lexical property affecting reaction latencies. Imageability (the ease with which a word evokes a mental image), cognate status (similarity of two words across languages in form and meaning), familiarity of the words and word length amongst others are word attributes that have generated varying degrees of investigation and have been shown to affect the speed at which words are recognised and produced. Another relevant word property is age of acquisition (AoA). Its effect in word processing times has been proved to be as robust as the effect of word frequency. The AoA effect has been observed in the same tasks in which word frequency is detected, leading researchers to suggest that AoA and word frequency might affect the same lexical stage or processes (Ellis & Lambon Ralph, 2000; Monaghan & Ellis, 2002a). Despite its empirically demonstrated relevance, AoA has been somehow ignored in the construction of most models of lexical access.

The work that has been done regarding age of acquisition and its effect in the second language of bilinguals has been mainly focused on the influence of how old you are when you start learning an entire second language. However, bilingual studies regarding the age at which individual words are acquired (AoA) are scarce. Yet the understanding of how the AoA of each word operates and exerts its influence in the language system can be elicited from the study of the AoA effect in bilinguals, in particular those bilinguals who have acquired the second language late in life.

The goal of the present thesis was to explore the AoA effect in a second language acquired during adulthood. By doing so the issue of whether age or a critical period is the essential factor in the AoA effect was examined. Chapter Two consists of a pilot investigation of the AoA effect in Spanish and English as first languages. Chapter Three will address the issue of whether or not lexical processing in a second language will be influenced by the AoA variable. Chapter Four, will assess whether first language AoA and second language AoA effects are independent of each other. Evidence of independent effects will suggest that AoA is lexically rather than semantically located. Chapter Five will address Ellis and Lambon Ralph's (2000) AoA theory that, based on the performance of a connectionist network, situates the AoA effect in the links between representations. Finally, the AoA effect will be further studied in a word translation task. This semantic task will determine the importance that AoA has, not only in the recognition and production of words, but also in their comprehension. It will also assess the unequivocal influence of AoA on the bilingual lexical domain. The results of these experiments will then be discussed in terms of their implications for current theories of AoA and current theories of bilingual word recognition and production.

The present Chapter will start with an examination of the definitions and dimensions of bilingualism followed by the latest views on how the words are organised in the bilingual mind. The most influential bilingual models on word recognition and production will then be reviewed. Finally, past research on AoA will be described, along with the theories that have proposed an explanation for the AoA effect, its nature and location.

1.2 Bilingualism

1.2.1 Definitions

Bilingualism is a difficult notion to define. It is complicated to find a single definition broad enough to capture all instances of individuals who are called 'bilingual'. The popular view understands bilingualism as the ability to speak two languages perfectly. This was the idea considered by Bloomfield (1933), an influential linguist who defined bilingualism as "the native-like control of two languages" (pp.

55-56). Although it is possible to find such bilingual people, it will exclude most individuals since very few people have the opportunity to develop a native-like competence in two languages. Other authors placed bilingualism at the other end of the scale: Macnamara (1966) defined a bilingual as a person who possesses at least one of the language skills (speaking, listening, reading, & writing) to a minimal degree in a second language.

Between these two extremes it is possible to find a whole array of definitions. Some authors (e.g., Hamers & Blanc, 1989; Baker, 1993) have underlined the methodological problems of such definitions, as having insufficient precision and being difficult to operationalise. What is meant by native-like competence or what is meant by minimal? How much is it necessary to know to be considered bilingual?

Grosjean (1989) offered a holistic view of bilingualism as opposed to the most renowned fractional view that traditionally divided bilinguals into two groups: the 'real' bilinguals who are fully competent in the two languages and all the others who are special types of bilinguals: 'unbalanced', 'semilingual', etc. The holistic view conceives the bilingual as a person who has two separate language competences, which are similar if not equal to the two corresponding monolinguals. From this functional perspective, bilingualism is "the regular use of two languages and bilinguals are those people who need and use two languages in their everyday lives" (Grosjean, 1992, p.51). Different proficiency in the languages of a bilingual is common because most bilinguals use their second language for different purposes and functions.

It is rare that the same level is needed for every skill in the two languages (Grosjean, 1982).

1.2.2 Determining factors in bilingualism

The bilingual population constitutes a very heterogeneous group. There are a large number of factors involved in the acquisition of a second language and therefore in the ultimate achievement of bilinguality. The factors that will be discussed in detail in the present review are those crucial to understanding the bilingual group investigated in the current thesis.

1.2.2.1 Competence

The level of competence achieved by each bilingual is closely related with other factors such as the need and use of languages, age of acquisition, context of acquisition, socio-cultural factors, etc.

The level of proficiency is a factor commonly used to classify or distinguish between different types of bilingualism. Hence, balanced bilinguals are those who have an equivalent fluency in both languages, normally at a native-like level. This group is composed of those individuals who learnt both languages early in childhood and use them at an equal level in time and situations. Dominant bilinguals possess a better proficiency of one of the two languages, often the mother tongue. The loss of the first language is rare but can also occur. Children exposed to a second language and deprived of the use of the mother tongue are particularly vulnerable to first language attrition, especially prior to the age of 7 (Harley & Wang, 1997). This reveals that a high level of competence in early second language acquisition is not an automatic outcome but depends on the use and presence of both languages in the child's environment.

1.2.2.2 Age of acquisition[1] and critical period

The age at which a second language is acquired has been shown to be an important factor in the explanation and understanding of why bilinguals achieve different levels of proficiency (Long, 1990; Palij, 1990; Mägiste, 1986; Snow & Hoefnagel-Höehle, 1978). Indeed, differences observed between the level of attainment of children and adults have led many researchers to distinguish between early bilinguality versus late bilinguality.

The age of acquisition factor has been commonly considered the major determinant of proficiency in L2. It has been traditionally thought that in order to achieve a native like competence in a second language, introduction is necessary during early childhood. This notion derives from the critical period hypothesis. Lennenberg (1967) was one of the first to apply the critical period notion to the acquisition of language. The critical period was described as a specific time period in which the acquisition of language must occur. The critical period account for language has generated an extensive amount of research. Regarding the acquisition of the first language, most researchers agree that early deprivation of language can cause severe linguistic deficit. Studies have

[1] The age of language acquisition referred to here, must not be mistaken with the age of acquisition variable that is mentioned later relating to the age or order at which words are acquired.

been based on cases of children who for different reasons have suffered linguistic isolation, normally due to social deprivation or deafness. These children show poor achievement in all linguistic aspects if language is introduced after early childhood (Grimshaw, Adelstein, Bryden, & MacKinnon, 1998; Long, 1990). Exact timing is difficult to determine, since research depends on the age at which the challenged child is detected. Newport (1990) reported that linguistic competence might be deficient if the first language is introduced after the age of six. These findings support the idea of a critical or sensitive period for the acquisition of the first language that is generally accepted among psycholinguists. However, great controversy exists among those researchers who have sought to apply the critical period hypothesis to the acquisition of a second language. Critical period proponents rely on the apparent inability of older learners to achieve native-like proficiency if the initial exposure starts beyond a certain age. The available data suggests the existence of not just one critical or sensitive period but different maturational constraints for the different linguistic aspects of language. Thus, acquisition may need to start before the age of 6 (Long, 1990) if native-like phonology is to be achieved; before the age of 15 for morphology and syntax (Patowski, 1979). Johnson and Newport (1989) detected a linear decline in grammatical abilities starting around the age of 8 through to puberty.

Underlying neurological changes as an explanation for the age differences found in the acquisition of the first and second language are as yet poorly understood and controversial. Among the different theories of brain changes and maturation, the process of myelination might be the more promising for those who support the concept of a critical period. Different cortical areas myelinate at different times, offering a potential biological explanation for the existence of different sensitive periods for the different aspects of language. The basic idea is that synaptic plasticity is reduced in highly myelinated areas. Primary sensory-motor areas are myelinated first, followed by higher-order associations. Thus, around puberty the language cortex is left with reduced plasticity after which language learning ability may also be reduced (Pulvermüller & Schumann, 1994).

1.2.2.3 Sociocultural and personality factors

Factors such as social class, ethnic identity etc., also play an important and complex role in the acquisition of a second language. It is considered that these factors do not determine the learning process or the state of bilinguality, but rather the social conditions and attitudes associated with them. However, other variables such as motivation, affective state, aptitude, learning style, and personality affect the learning process and the ultimate attainment (Ehrman, 1996; Ellis, 1994; Gardner & Lambert, 1972). Details of the importance of these factors in second language acquisition are not discussed here in depth, as they do not hold relevance for the present thesis.

1.2.3 Word knowledge organisation in bilinguals

How the word knowledge is organised in bilingual memory has been a topic of research that has captured the attention of linguists and cognitive psychologists for the past fifty years. There have been a number of attempts to understand how two languages might be represented in the brain. How the languages might be connected and whether the cognitive subsystems that encapsulate the two languages change with the development in second language proficiency. Some of the more important contributions to this research are reviewed below.

1.2.3.1 Coordinate, Compound and Subordinative systems.

Weinreich (1953) suggested that the way in which the two languages of a bilingual are learned and used influences the way they are encoded in the brain. He proposed three possible systems of bilingual lexical representation: compound, coordinate, and subordinative systems. They differ in the number of conceptual storages (one or two) and in the way conceptual representations are accessed from an input word.

The compound system is formed by two lexical storages (one for each language) and a single conceptual system shared between the two languages. The compound system is the result of learning two languages in one context where they were used interchangeably. In the mind of a compound bilingual a single concept has one mental representation, but two verbal labels attached to it. The coordinate system is composed of two lexical storages and two conceptual systems, one for each language. It is the result of learning each language in a separate environment or context such as one language being spoken at home and the other at school. The subordinative system corresponds to those bilinguals who have learnt a new language with the help and by comparison with the other. In these cases the referents for the new learned words are not their meanings, but their equivalent translations into the first language. Thus, in the subordinative system the second language (L2) words have direct links with first language (L1) words but no direct links with the conceptual representations.

Weinreich (1953) pointed out that this classification is not rigid but flexible. He suggested that a transition would eventually occur from a subordinative type of bilingual to a coordinative type with an increase of proficiency in the second language. He also suggested that even words could differ in the way they are represented with some words being of the coordinate type while others of the compound type.

1.2.3.2 Word Association and Concept Mediation models

Word association and concept mediation models have been more recently proposed. They distinguish between two types of representation in bilingual memory; a lexical and a conceptual representation. These models resemble Weinreich's subordinative and compound language configurations.

The word association model assumes that the words in the second language are directly connected with their translation equivalents in the first language. Only first language words have direct access to their concepts. According to the word association model a second language word has to be translated to the first language in order to access its meaning.

The concept mediation model, however, does not assume direct links at a lexical level but direct connections of both lexicons to a common semantic representation. The word association and concept mediation models can be seen in Figures 1.1 and 1.2 respectively.

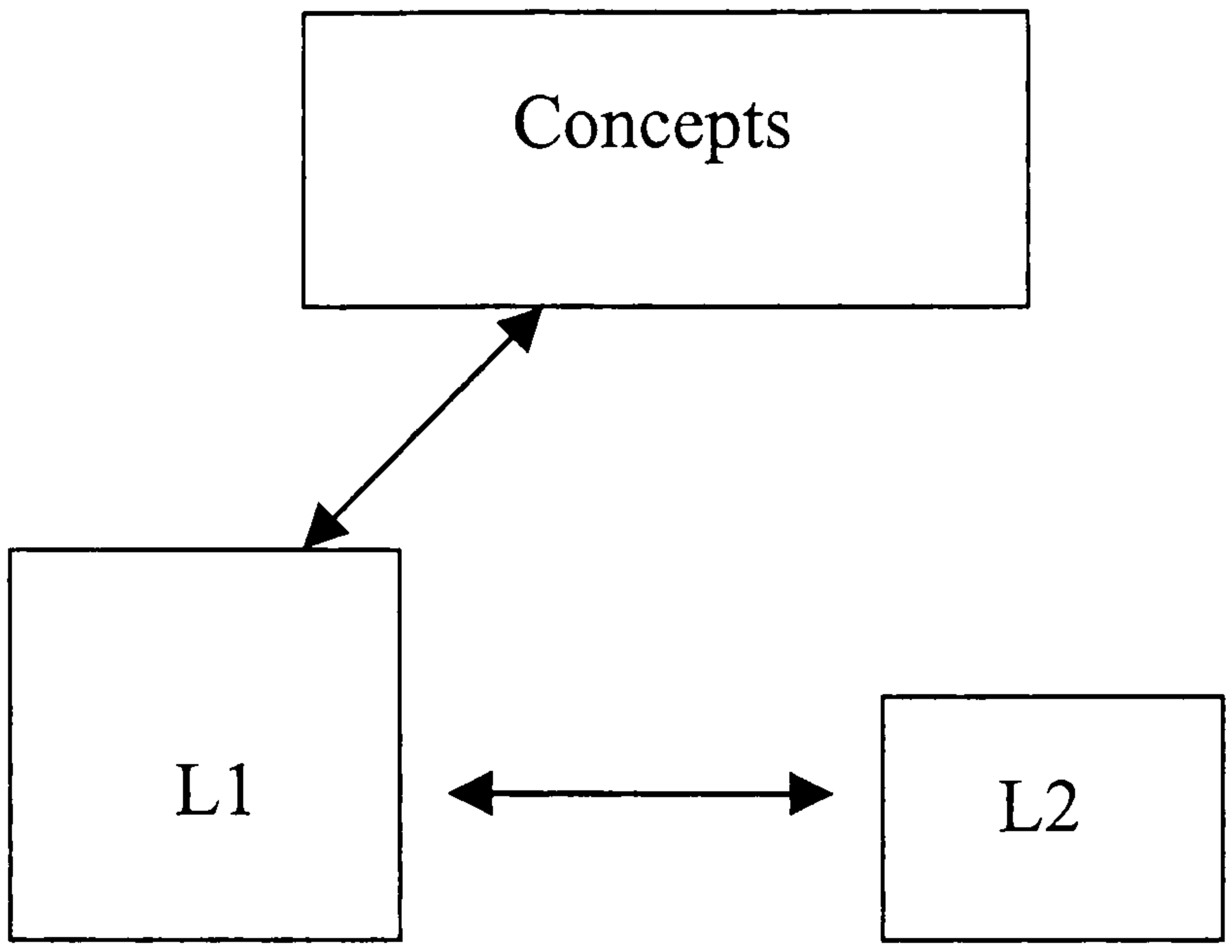

Figure 1.1 The word association model of bilingual memory (Potter, So, Von Eckardt, & Feldman, 1984). Words in the second language are directly connected with their counterparts in the first language and indirectly connected to the conceptual representations.

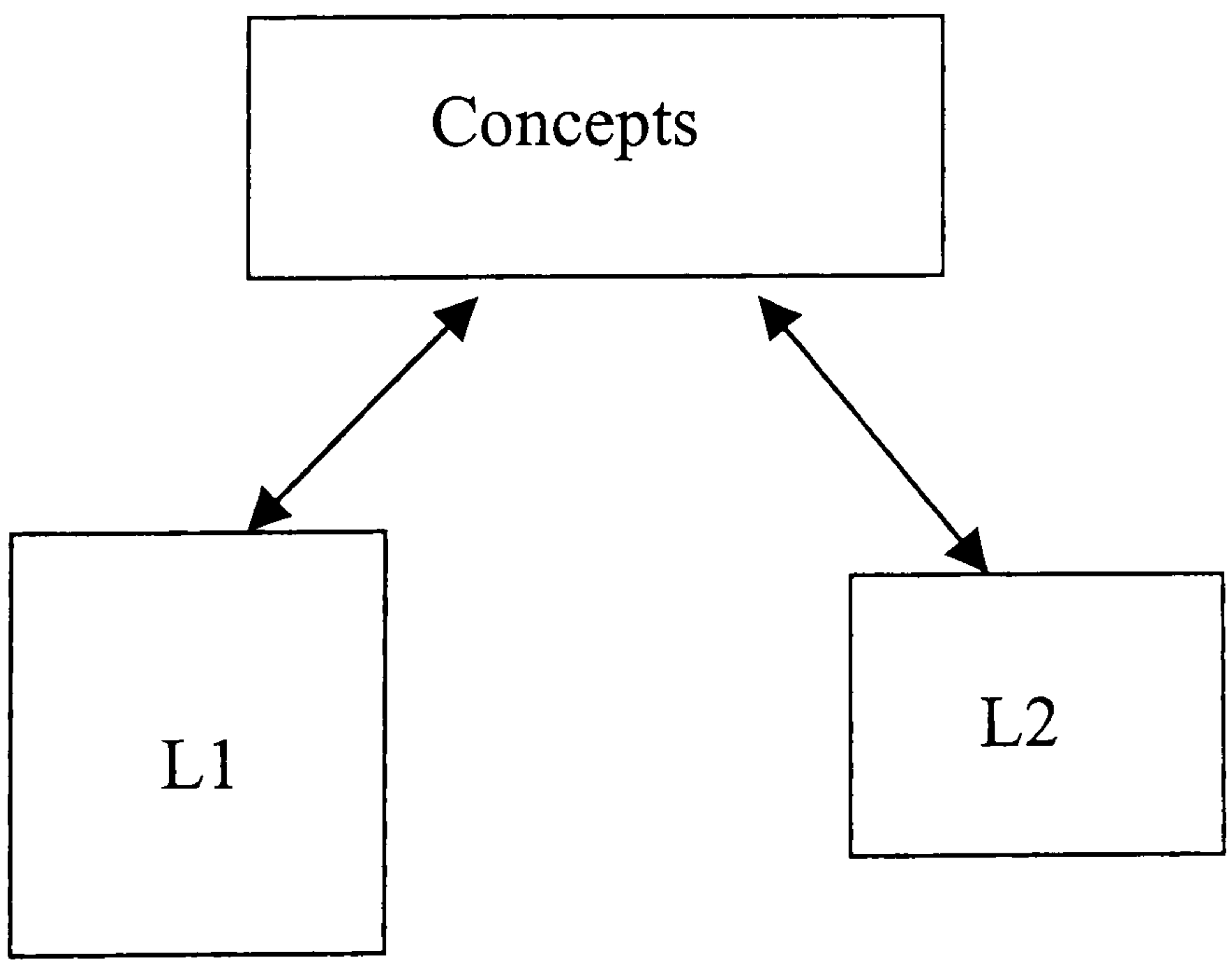

Figure 1.2 The concept mediation model of bilingual memory (Potter, So, Von Eckardt, & Feldman, 1984). Words in the second and first language are linked directly with their conceptual representations.

Potter, So, Von Eckardt, and Feldman (1984) tested these models in two experiments, one carried out with proficient bilinguals and the other with relatively novice bilinguals. The concept mediation hypothesis predicts little or no difference in the time needed to name a picture in L2 and to translate a word from L1 to L2 since both tasks require first an access to the meaning of the picture or the word in L1 and a subsequent access to the L2 word form. The word association hypothesis, however, predicts that translating from L1 to L2 will take less time than naming pictures in L2 since translation can be accomplished through direct lexical links and picture naming requires the extra step of retrieving the concept first and then the L2 word. Potter et al. (1984) showed that proficient bilinguals and not-so-proficient bilinguals translated words into L2 and named pictures in L2 at approximately the same speed. The results were taken as support for the concept mediation model.

A criticism that Potter et al.'s (1984) study has received is that the bilingual participants were perhaps proficient enough to have developed a conceptual link to both languages. Kroll and Curley (1988) carried out a study using balanced bilinguals and a group of novice bilinguals with less fluency in the second language than those in Potter et al.'s (1984) study. Balanced bilinguals named pictures and translated words at approximately the same speed. However, unlike Potter et al.'s (1984) study, the novice bilinguals were faster to translate words than to name pictures in the second language. Overall these results support both the concept mediation and the word association model, suggesting an important difference in the language organization of novel and proficient bilinguals. It is conceivable that a developmental shift occurs and an initial word association language organization eventually becomes conceptually mediated. This developmental shift was captured in the revised hierarchical model proposed by Kroll and Stewart (1994).

1.2.3.3 A revised model of lexical and conceptual representation in bilingual memory

Kroll and Stewart (1994) proposed the revised hierarchical model (RHM), a hybrid model that combines the assumptions of the word association and the concept mediation model.

The translation asymmetry found in previous studies (Chen & Leung, 1989; Kroll & Curley, 1988), with faster translation latencies from L2 to L1 than from L1 to L2, is accounted in the model as the extra semantic step required to translate in one direction (from L1 to L2) but not in the other (from L2 to L1), just as monolingual research argues that naming pictures takes longer than naming words due to the inevitable semantic involvement in picture naming that is absent in naming words. To accommodate these new findings, Kroll and Stewart (1994) proposed the revised hierarchical model. According to the model, lexical and conceptual links are created in the course of learning a second language. The strength of these connections varies depending on the fluency in L2. In general, for those bilinguals more fluent in one language than the other the model states that word forms in L1 are strongly linked to their semantic representations and weakly connected to L2 word forms. Some L1 words would not even have yet a L2 word equivalent. Direct connections between words in L2 and semantics are also formed but these are weak. L2 word forms are strongly linked to word forms in L1 and all L2 words will have a translation equivalent in L1 to be linked to. The lexical connections assumed by the model are bi-directional but, possibly as a result of the common practice of learning words in a new language by associating them with their translation in L1, the lexical links are stronger from L2 to L1 than from L1 to L2. The L2 lexicon is assumed to be smaller than the L1 lexicon, as bilingual speakers typically know more words in their first language than in their second language. The revised hierarchical model can be seen in Figure 1.3

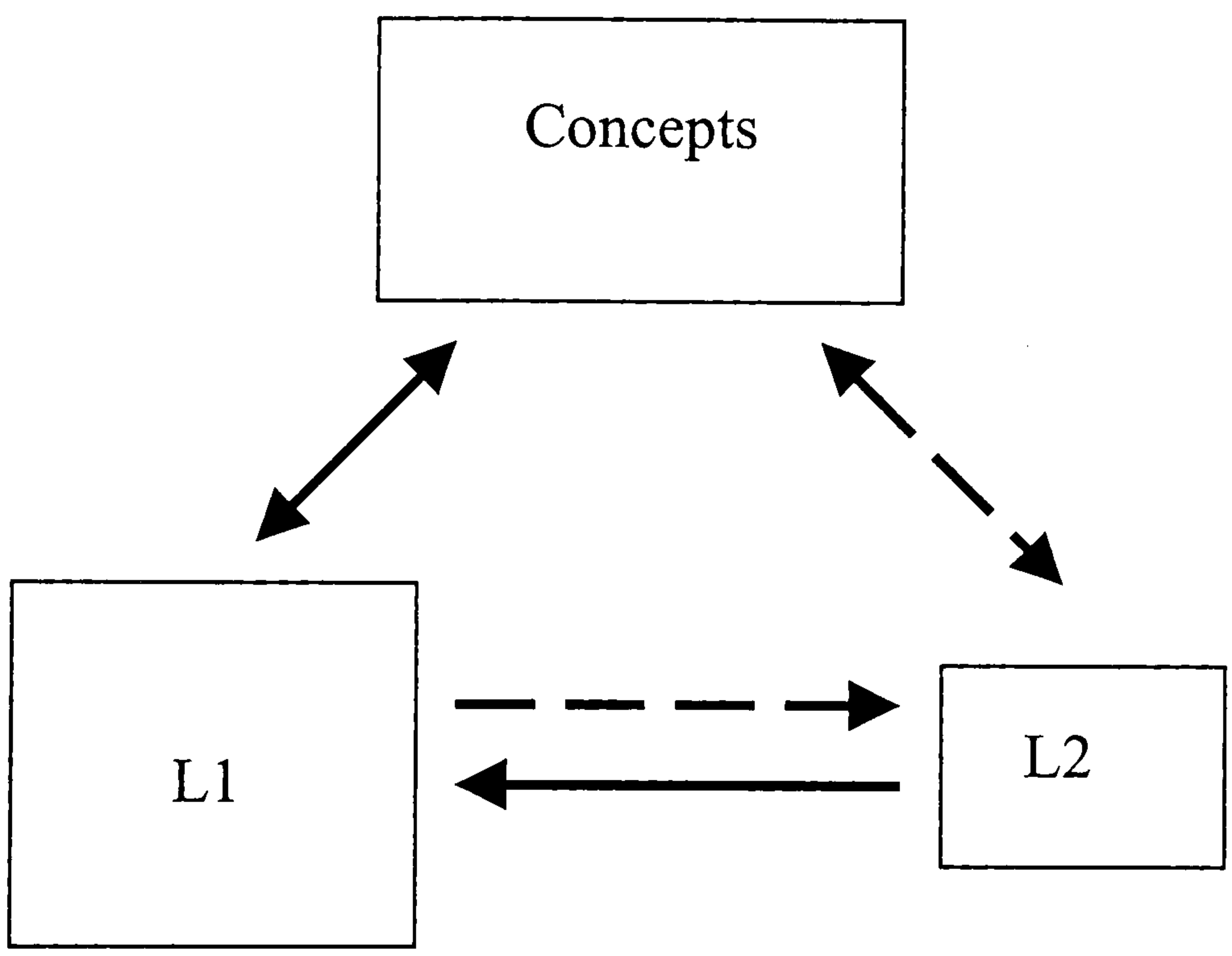

Figure 1.3 Revised hierarchical model of bilingual memory (Kroll & Stewart, 1994). Words in L2 are strongly linked to their translations equivalents in L1 but weakly linked to their semantic representations. However, words in L1 have strong links with their conceptual representations but are weakly connected with their translation equivalents in L2.

1.2.4 Bilingual models of word recognition and production

Since individuals have the potential to speak one, two or more languages, models of word recognition and production for the monolingual and bilingual case should not differ greatly in their basic principles of lexical processing. For this reason most bilingual models have extracted notions from monolingual models and have adapted them to the bilingual model. This is the case of the two models reviewed below. The Bilingual Interactive Activation model (Van Heuven, Dijkstra, & Grainger, 1998) is based on the interactive activation model proposed by McClelland and Rumelhart (1981) while the Inhibitory Control model (Green, 1998) incorporates Levelt's (1989) division of the lexical items into lemmas and lexemes.

1.2.4.1 The bilingual interactive activation model (BIA)

BIA (Van Heuven et al., 1998) is a model of bilingual word recognition. The model attempts to offer a processing and organizational account of the bilingual mental lexicon. In terms of lexical organization, Van Heuven et al. (1998) initially postulated an integrated lexicon for both languages. This suggestion was inferred from the results of progressive demasking and lexical decision tasks where it was shown that the frequencies of the orthographic neighbours from the non-target language influenced word recognition latencies. However, in a subsequent study an alternative lexical explanation was offered (Dijkstra, Grainger, & Van Heuven, 1999). It was suggested that homographs (words with identical orthographic form across languages) and cognates (words with identical orthography and meaning across languages) may shared the same representations. The remaining lexical entries would belong to independent L1 or L2 lexicons. However, later versions of the model (Dijkstra & Van Heuven, 2002) have suggested independent representations in L1 and L2 even for homographs. Cognates are considered to have a special representation.

In terms of word recognition processes the model emphasises the non-language selective nature of bilingual word access. Thus, an input letter string causes parallel activation of all the words (in either language) that share letters with the input letter string. Activated words compete for selection until one of them surpasses its activation threshold and is recognised. A layer of language word units controls the relative activity of L1 and L2 sending top-down inhibitory effects on the non-target language words.

The activation thresholds of each word depend on their frequency and in general the model assumes reduced subjective frequencies for L2 words. A schematic representation of the model depicting an integrated lexicon can be seen in Figure 1.4

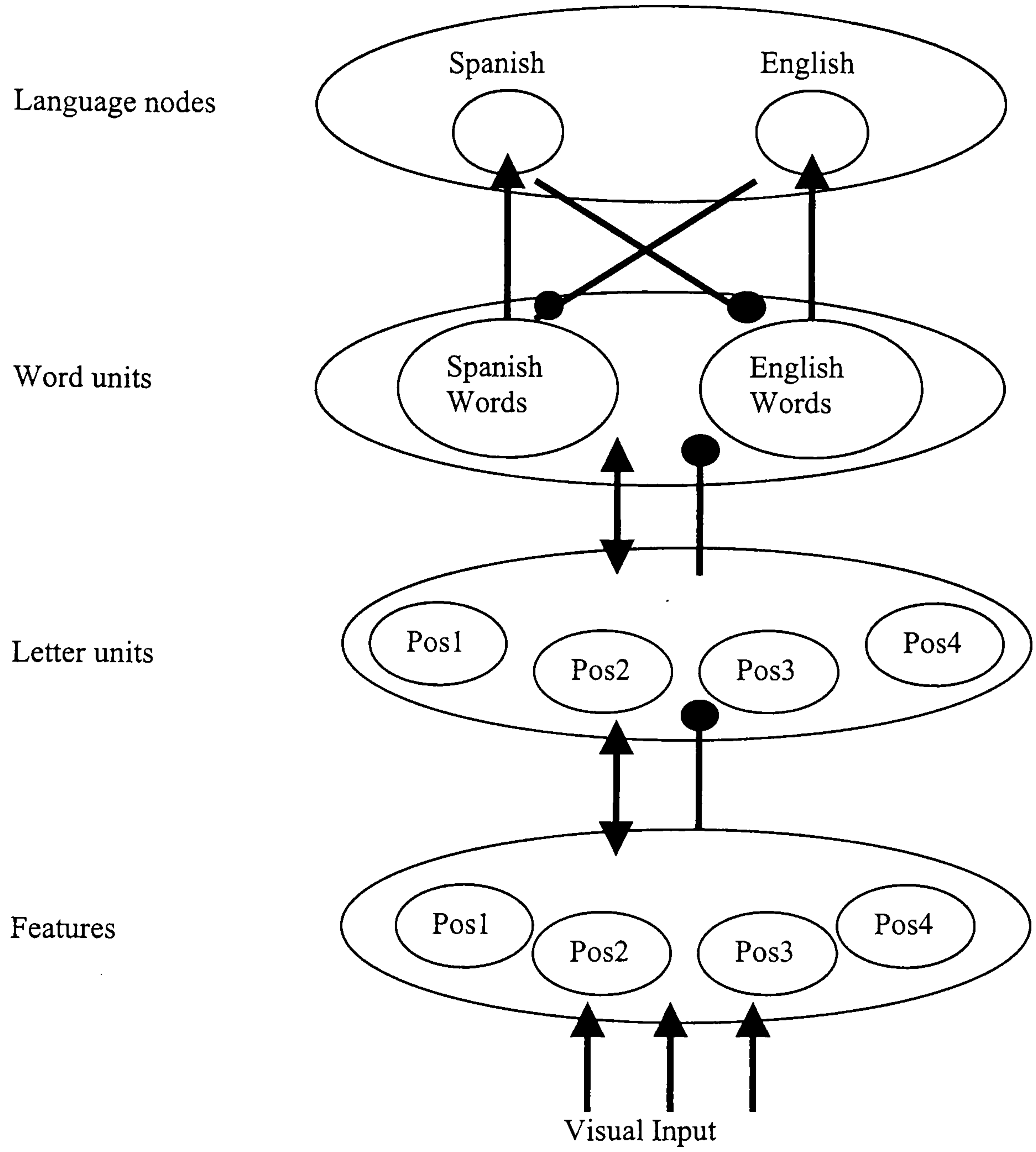

Figure 1.4 Bilingual Interactive Activation model, BIA (Van Heuven, Dijkstra, & Grainger, 1998). The visual input creates a parallel activation of a number of words in both languages that will compete for selection.

1.2.4.2 The inhibitory control model (IC)

The IC model (Green, 1998) is a theoretical account of the regulatory processes by which bilinguals use one language without interferences from the other. The IC model proposes multiple levels of control of the bilingual lexico-semantic system. It follows Levelt's organisational principles assuming that every concept in the lexico-semantic system is linked to a lemma (syntax information) whose selection leads to the activation of the associated word form or lexeme (phonological information).

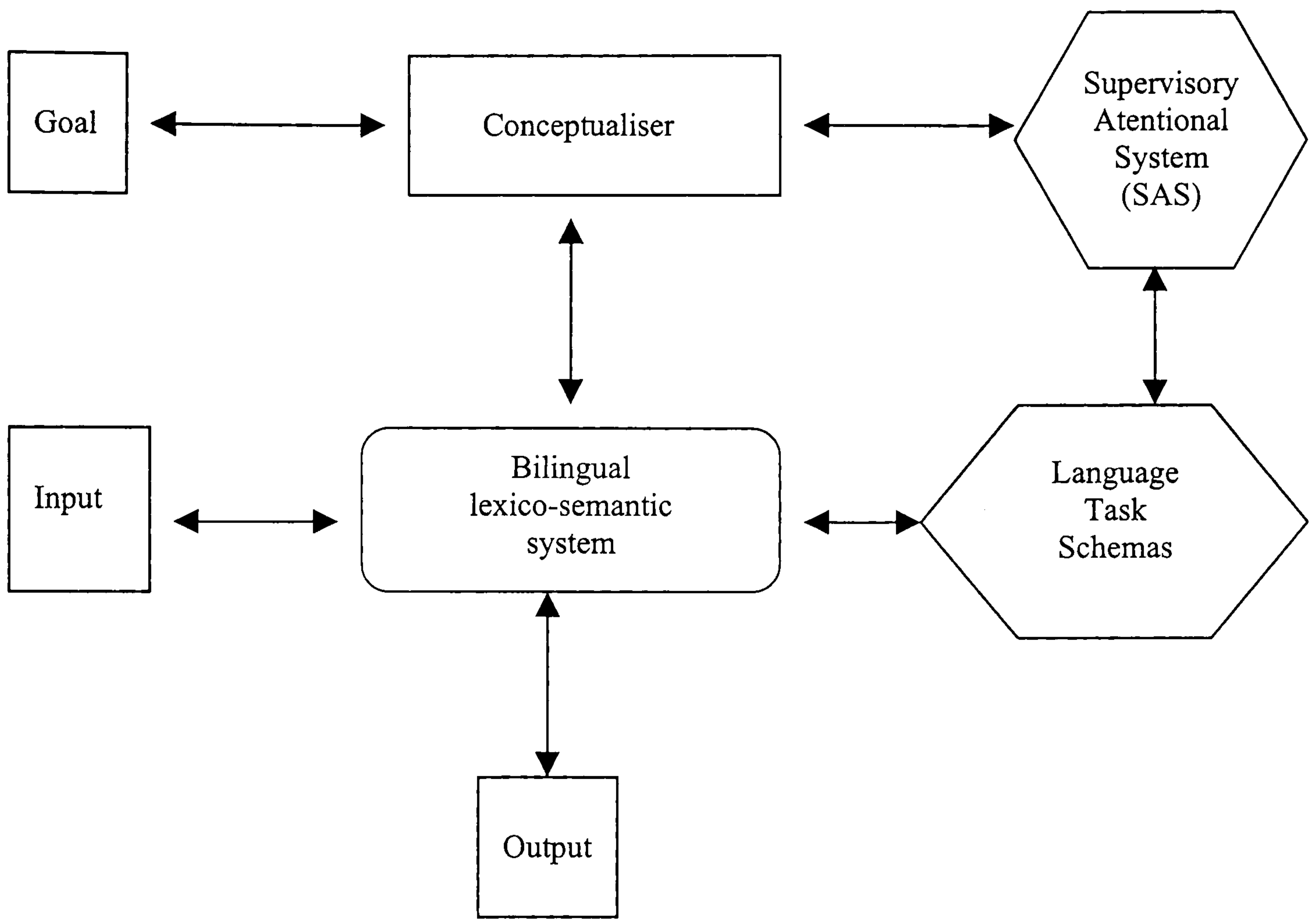

Figure 1.5 The Inhibition Control model, IC (Green, 1998). The regulation of the bilingual lexico-semantic system is brought about by multiple levels of control.

According to the model, before any linguistic task can be performed, a task schema must be engaged; for example, naming a picture in L1 or L2, translating from L1 to L2 or vice versa, etc. In addition a language task mechanism is proposed. Its function is to regulate the lexical output. For instance, it is assumed that an input letter string will activate associated lemmas irrespective of the language. The language task schema, governed in turn by an attentional system, is in charge of maintaining the activation of the target language lemmas while inhibiting the lemmas of the non-target language. This inhibitory mechanism provides an explanation for the ability of bilinguals to selectively speak in one language or the other. It also predicts the often-found asymmetry in the cost of switching from one language to the other (Meuter & Allport, 1999; Macnamara, Krauthammer, & Bolgar, 1968). The activation of lemmas from the two languages creates a competition that is resolved by inhibiting the lemmas from the non-target language. Inhibition is reactive, therefore the more active a non-target lemma, the more inhibited it will be. Activating inhibited lemmas is a function of the prior amount of suppression. As lemmas in L1 get higher activation than lemmas in L2 the switching cost predicted by the model is asymmetric.

1.3 Age of acquisition (AoA)

1.3.1 The age of acquisition effect

Rochford and Williams (1962) observed that dysphasic patients showed a degree of difficulty naming objects that was closely related to the age of word acquisition in children. Carroll and White (1973a) showed that the Rochford and Williams (1962) presaged age of acquisition affected object naming RT. Since then it has been widely demonstrated that, other factors being equal, words acquired early in life are recognised and produced faster than words acquired some time later.

The AoA variable has been investigated in a number of different tasks. In the current review only the AoA effect within picture naming, word naming and lexical decision processes will be discussed. Although the effect of AoA has also been reported in other tasks such as memory tasks, and face recognition tasks, such effects are not of primary interest for the current study and therefore they will not be examined here.

1.3.2 Measures of AoA

The AoA measure adopted by most researchers consists of adult estimations of the age they believe they were when they acquired a particular word. Carroll and White (1973b) were the first to collect a rated measure for the AoA for over 100 words. Participants rated each word on a nine-point scale where 1 signified learnt before 2 years of age and 9 learnt after the age of 13 years. Aware of the emerging importance of AoA, Gilhooly and Logie (1980) collected ratings for a corpus of 1,944 words. The ratings followed the same instructions as Carroll and White (1973b) except that a seven-point scale rather than a nine-point scale was used. The scale ranged from 1, learnt before 2 years of age to 7, learnt after the age of 13 years. Gilhooly and Logie' s (1980) corpus and methodology have been widely used ever since.

Gilhooly and Logie's (1980) AoA ratings showed an inter-group reliability of 0.98. This means a high agreement amongst raters on the factor they were rating. However, it is also important to assess the validity of subjective measures. Regarding AoA it is vital to prove that the AoA ratings are directly assessing the effects of when words were learnt and not their familiarity, frequency of occurrence, etc. (Morrison & Ellis, 1995, 2000).

Most studies have assessed the validity of subjective AoA measures by correlating AoA ratings with objective measures of AoA. High positive correlations between the two measures will prove that rated AoA is similar to objective AoA and therefore a valid measure to use in the study of the AoA effect. Researchers have collected objective measures of AoA in a number of different ways. Carroll and White (1973a) showed a correlation of 0.85 between subjective AoA ratings and the age at which children were able to name such items. The norms from the Mill Hill vocabulary test that gave the mean age at which children learned to read words correctly were taken by Gilhooly and Gilhooly (1980) as their objective measure of AoA. They reported a correlation of 0.93 between rated and objective AoA. Jorm (1991) reported a longitudinal single case study in which the different ages at which Ruth, the author's daughter, learnt to speak and read 94 nouns was recorded. At the age of nine and eleven the child rated the same 94 nouns. The correlations between the objective and rated measures were 0.71 at nine years of age and 0.79 at eleven years of age. More recently, Morrison, Chappell, and Ellis (1997) collected objective AoA measures for 297 pictures. Two hundred and eighty children participated in the study. Their ages ranged from 2 years and 6 months to 10 years and 11 months. They were asked to name each picture and were divided into groups of 20 with 6 to 12 months difference between groups. The objective AoA value for each word corresponded to the age band of the group in which at least 75% of the children correctly recognised and named the picture (with or without help from a phonetic, initial sound, cue). Morrison et al. (1997) reported a correlation of 0.76 between subjective and objective age of acquisition measures.

Taken together, the results of these studies show adults are able to judge with considerable precision the order at which they and others acquired words. The advantages of the use of objective AoA measures are obvious. They assess directly and without doubt the real age at which words were acquired. They will be the desirable measure for experimental use whenever possible. However, objective AoA measures are often laborious to obtain. Rated AoA measures, simple to collect, have proved to be a valid substitute of the more desirable objective AoA measure.

1.4 The picture naming task

The picture naming task consists of the presentation of pictures of single objects to individuals who are asked to name them aloud. Reaction times (delay between the appearance of the picture and the onset of the participant's response) and/or number of correct responses are the standard measures subjected to statistical analysis.

1.4.1 Factors affecting picture naming

At least three main lexical processes have been suggested to be indispensable to name pictures of objects effectively. These are: object recognition, object comprehension and lexicalization processes (Warren & Morton, 1982). The visual features of the perceived object are the first to be analysed. If the object is recognised as familiar an analysis of its semantic information (knowledge of its structural and functional characteristics such as 'two legs', 'plumage', 'lays eggs', etc.) will follow. The appropriate word form ('bird') can then be selected in the so-called lexicalization process.

Two views have been proposed to explain the mechanisms involved in the lexicalization process. One view assumes that from the triggered semantic representations ('two legs', 'plumage'...) activation is sent directly to the phonological forms of the words stored in the phonological output lexicon (Humphreys, Riddoch, & Quinlan, 1988). An alternative view divides the lexicalization process into two steps. First the semantic representations activate the 'lemmas' that in turn will spread activation to the 'lexemes' (Levelt, 1989; Jescheniak & Levelt, 1994). Lemmas are conceived as a level of word representation that mediates between the semantics and the lexemes or phonological representations of the words.

One approach to the study of which cognitive processes are involved in picture naming is through the investigation of the effects that different lexical properties have on object naming. Oldfield and Wingfield (1965) reported a negative relationship between the naming times to 26 pictures and the frequency of occurrence of their names. Thus, the higher the frequency of a name the shorter its naming time. The frequency variable has been intensively investigated ever since (Humphreys et al., 1988; Lachman, Shaffer, & Hennrikus, 1974). The robust frequency effects consistently found were challenged by Carroll and White (1973a, 1973b) who failed to find frequency effects in a study of picture naming times that for the first time controlled for age of acquisition. Consistent with Carroll and White's (1973a) study other investigations (Gilhooly & Gilhooly, 1979; Morrison, Ellis, & Quinlan,

1992) also failed to find frequency effects once AoA was controlled for. This fact lead researchers to argue that the frequency effects found in the past had in fact been confounded with AoA effects. However, two other alternative explanations have been offered to account for the failure to find word frequency effects. The first is the use of dated word frequency counts such as Kucera and Francis (1967) while the second is the use of the regression analysis technique over a low number of items causing a reduction on the statistical power of the analysis (Barry, Morrison, & Ellis, 1997; Monaghan, 2002). Subsequent studies with an increased number of items and more modern measures of word frequency have provided evidence of both frequency and AoA effects in object naming speed (Barry et al., 1997; Ellis & Morrison, 1998; Snodgrass & Yuditsky, 1996).

All the studies mentioned above have relied on multiple regression analysis. One of the problems associated with multiple regression analysis is that of multicollinearity. Multicollinearity occurs when two predictor variables are highly correlated just as word frequency and AoA are because high frequency words tend to be acquired earlier than low frequency words. High correlated variables violate the assumption of independency for regression, reducing its statistical power. In these cases the relative contribution of each variable to the task results is difficult to differentiate since a great proportion of the variance associated with one of the inter-correlated variables is embedded in the other variable.

Barry, Hirsh, Johnston, and Williams (2001) overcame the problems associated with multiple regression by using a factorial design in which frequency was orthogonally manipulated while controlling for AoA, familiarity, name agreement, image agreement, visual complexity and word length. No frequency effects were found on object naming speed. Meschyan and Hernández (2002) also studied AoA and word frequency effects in object naming using a factorial design. However, unlike Barry et al. (2001), they found frequency effects when AoA had been controlled for.

In conclusion, the word frequency effect in object naming is still a matter of debate. Recent studies have suggested that its effect is dependent of AoA effects and may be limited to late acquired words (Barry et al., 2001; Barry, et al. 1997; Meschyan & Hernández, 2002), in which case the proportion of late acquired items used will affect the likelihood of finding a significant frequency effect.

Name agreement has been described as the level of consensus amongst individuals on the name given to a particular picture. Name agreement affects the speed of naming objects with those pictures with high name agreement being named faster than pictures with low name agreement (Lachman, 1973; Lachman & Lachman, 1980). Two possible locations for the name agreement effect have been proposed. One situates the effect at the level of the structural representations, where pictures with low name agreement could be ambiguous, or more difficult to identify in the absence of a context. The other is located at a lexical level and argues that the availability of more than one correct name creates a competition that needs time to be resolved in pictures with low agreement (Barry et al. 1997; Vitkovitch & Tyrrell, 1995).

1.4.2 The AoA effect in picture naming

Carroll and White (1973a, 1973b) were the first to investigate the AoA effect. They aimed to clarify the frequency effect found by Oldfield and Wingfield (1965) in an object naming task. Oldfield and Wingfield (1965) had argued that word retrieval speed was a function of word frequency. However, Oldfield and Wingfield's study was based on only 12 participants and 26 stimuli and had failed to control for the age of word acquisition, a new variable that Rochford and Williams (1962) had speculated to be highly correlated with aphasic's accuracy at naming objects. Carroll and White's (1973b) experiment consisted of 103 pictures named by 37 participants. Out of six variables (two indices of word frequency, rated and objective AoA, number of letters and number of syllables) only AoA emerged as a significant predictor of object naming latencies. Carroll and White (1973b) concluded that AoA and not frequency was the key factor of naming latencies. They suggested that words are stored in mind chronologically and that this order had an important impact in word retrieval.

The striking absence of an effect of word frequency and the finding of a new word property provoked a thriving new line of research whose focus was the AoA effect. Consistent with Carroll and White (1973a, 1973b) there are a number of studies showing that the greatest proportion of variance on immediate object naming speed was explained by AoA (Barry et al., 1997; Ellis & Morrison, 1998; Gilhooly & Gilhooly, 1979; Kremin, Hamerel, Dordain, De Wilde, & Perrier, 2000; Lachman et al., 1974; Morrison et al., 1992). All of these studies have relied on multiple regression analyses, a technique that has allowed authors to show the AoA effect over and above other variables such as word frequency, familiarity, name agreement, word length, visual complexity, etc.

Factorial designs have also been used in the investigation of the AoA effect on picture naming (Barry et al., 2001; Ellis & Morrison, 1998; Meschyan & Hernández, 2002). Factorial designs allow an independent manipulation of the variable of study avoiding the problems that high correlated variables create when using multiple regression analysis. In this line Barry et al. (2001) examined AoA and repetition priming effects in a picture naming experiment in which AoA was subjected to an orthogonal manipulation. AoA affected immediate object naming across repetitions. The significant interaction found between AoA and repetition priming, with larger repetition priming effect for late than for early acquired words, was interpreted as evidence to situate the AoA effect at the level of lexical-phonological retrieval. This notion of a lexical locus for AoA will be further examined in the review of theories for AoA.

Barry et al. (2001) also explored the influence of AoA on delayed naming. The same pictures utilised in immediate naming were presented to 48 participants who had to name them once they disappeared from the screen (1500ms after onset of presentation). No AoA effect was found. This result, consistent with Ellis and Morrison's (1998) findings, ruled out the possibility of the AoA effect arising at the level of initiating spoken responses.

Overall, AoA is a well established effect in object naming latencies. Furthermore recent studies (Bogka, Masterson, Druks, Fragkioudaki, Chatziprokopiou, & Economou, in press; Colombo & Burani, 2002) reported AoA effects not only in the production times of object names but also in the naming times of action pictures.

A final source of data for AoA effects is the investigation of naming accuracy showed by participants with deficits in language processing. Lambon Ralph, Graham, Ellis, and Hodges (1998) explored the factors affecting object naming accuracy in 9 patients with semantic dementia. The naming success of the nine patients was determined by AoA along with object familiarity and word frequency. Bell, Davies, Hermann, and Walters (2000) analysed the naming accuracy of 26 patients before and after anterior temporal lobectomy. AoA was found to influence correct object naming pre-surgery and post-surgery. Similar results have been obtained in studies with patients with probable Alzheimer's disease (Cuetos, Martinez, Martinez, Izura, & Ellis, in press), in normal elderly adults (Hodgson & Ellis, 1998), in patients with aphasia (Cuetos, Aguado, Izura, & Ellis, 2002; Ukita, Abe, & Yamada, 1999), and in the semantic errors produced by a deep dyslexic patient (Gerhand & Barry, 2000).

1.5 The word reading task

The word reading task consists of the recognition and pronunciation of written words presented individually. Reaction times (speed at which the participant's response is produced after the presentation of the word) and/or reading accuracy are the standard measures subjected to statistical analysis.

Theories of word reading (and other complex lexical skills) have been traditionally based on descriptive models that by means of boxes and arrows explained normal and impaired word reading processes. These models have been useful in the understanding of the components involved in word reading. However, they have been recently supplemented with neural net or connectionist models. Neural net models are based on computational simulations and, unlike descriptive models, account for the operation of the components involved in word reading (Patterson, 1990).

Two influential connectionist models have attempted to explain the underlying mechanisms of normal and impaired word reading. These are the dual route cascade model (Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) and the parallel distributed processing model (Harm & Seidenberg, 1999; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989).

1.5.1 The dual route cascade model of word reading

The dual route cascade model (Coltheart et al., 2001) presents two possible pathways or routes for word reading, a lexical route that in turn is subdivided into a semantic and non-semantic route, and a non-lexical route. The subdivision of the lexical pathway makes this model effectively a triple route model although the model emphasises the fundamental lexical, non-lexical division. In the lexical route familiar words are represented as units in the orthographic input lexicon. A letter string presented to the model will activate the lexical and non-lexical route. In the lexical route each orthographic representation is activated by its specific printed word form and in turn sends activation to its meaning, stored in the semantic system. The semantic representation then activates the word's spoken form stored in the phonological output lexicon which will activate a final phoneme system where the output word will be produced. The phonological form of each word can be directly accessed from its orthographic representation by-passing its meaning. This subdivision of the lexical route into semantic and non-semantic was devised to account for the conditions under which normal and impaired word reading is, or is not, influenced by word meaning. The non-lexical route consists of a mechanism that translates letters into sounds and is called grapheme-to-phoneme conversion. For common or familiar words the non-lexical route is slower than the lexical route since the rate of activation in the lexical route is proportional to word frequency. High frequency words activate the phoneme system through the lexical route before the non-lexical route reaches phonology. However, low frequency words are processed at the same rate by the two routes. If the word is a low frequency exception word, two different outcomes are generated by each route and they will create competition. The time required to resolve the competition explains the interaction between frequency and regularity observed in a number of studies (Parkin, 1982; Waters & Seidenberg, 1985).

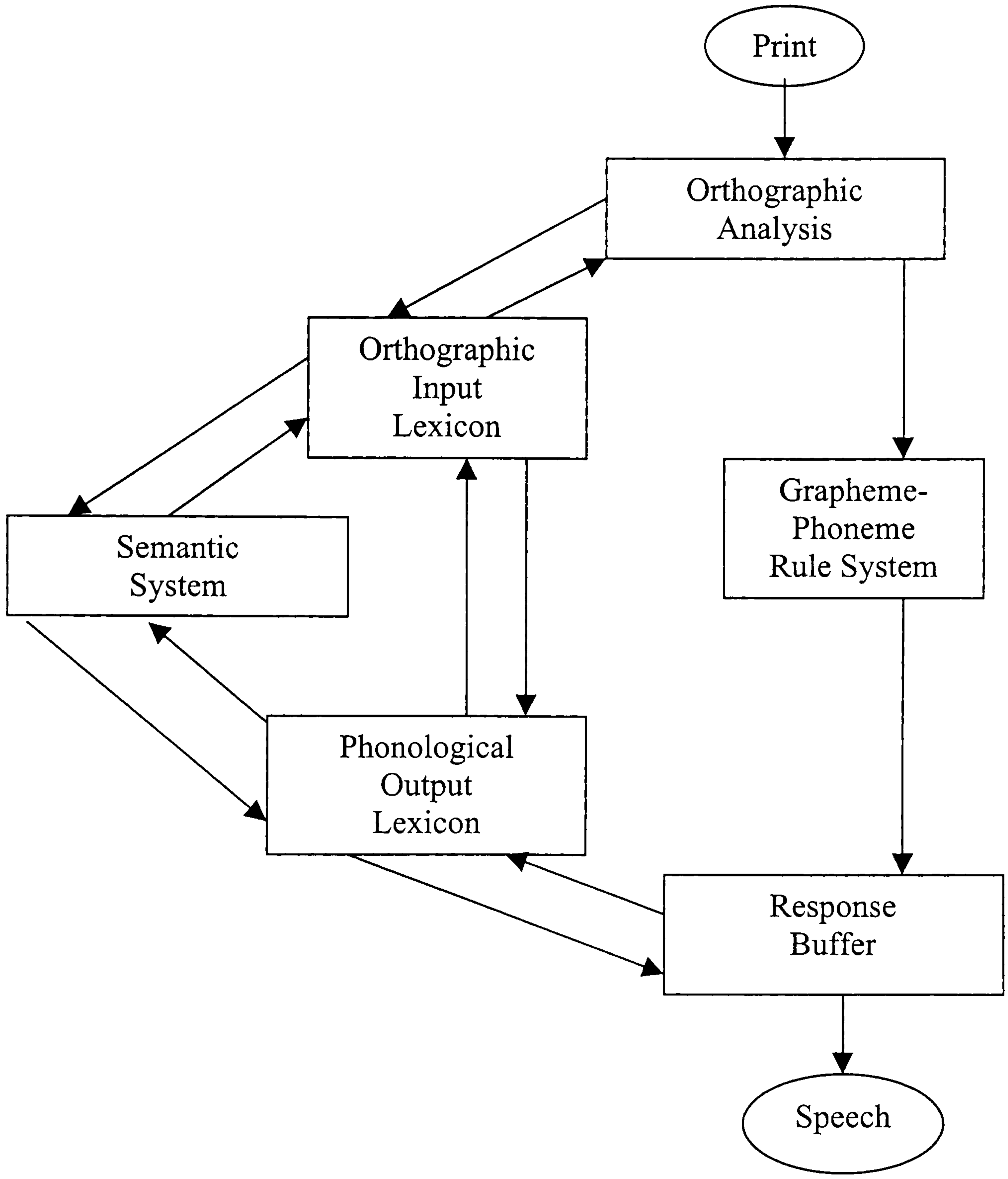

Figure 1.6 The dual route cascade model of skilled adult reading (Coltheart et al., 2001). The non-lexical GPC route is used for the correct reading of nonwords. Regular words are successfully read through the non-lexical and lexical route while irregular words will be read correctly only through the lexical route. The semantic route may be involved when reading via the lexical pathway, especially when the direct lexical route is damage as in deep dyslexia.

1.5.2 The parallel distributed model of word reading

The parallel distributed processing models, PDP (Harm & Seidenberg, 1999; Plaut et al., 1996) state that the orthographic, phonological and semantic information held by each word is represented by distributed patterns as opposed to the whole word unit representations postulated by the dual route model. The model of skilled adult reading provided by Plaut et al. (1996) can be seen in Figure 1.7.

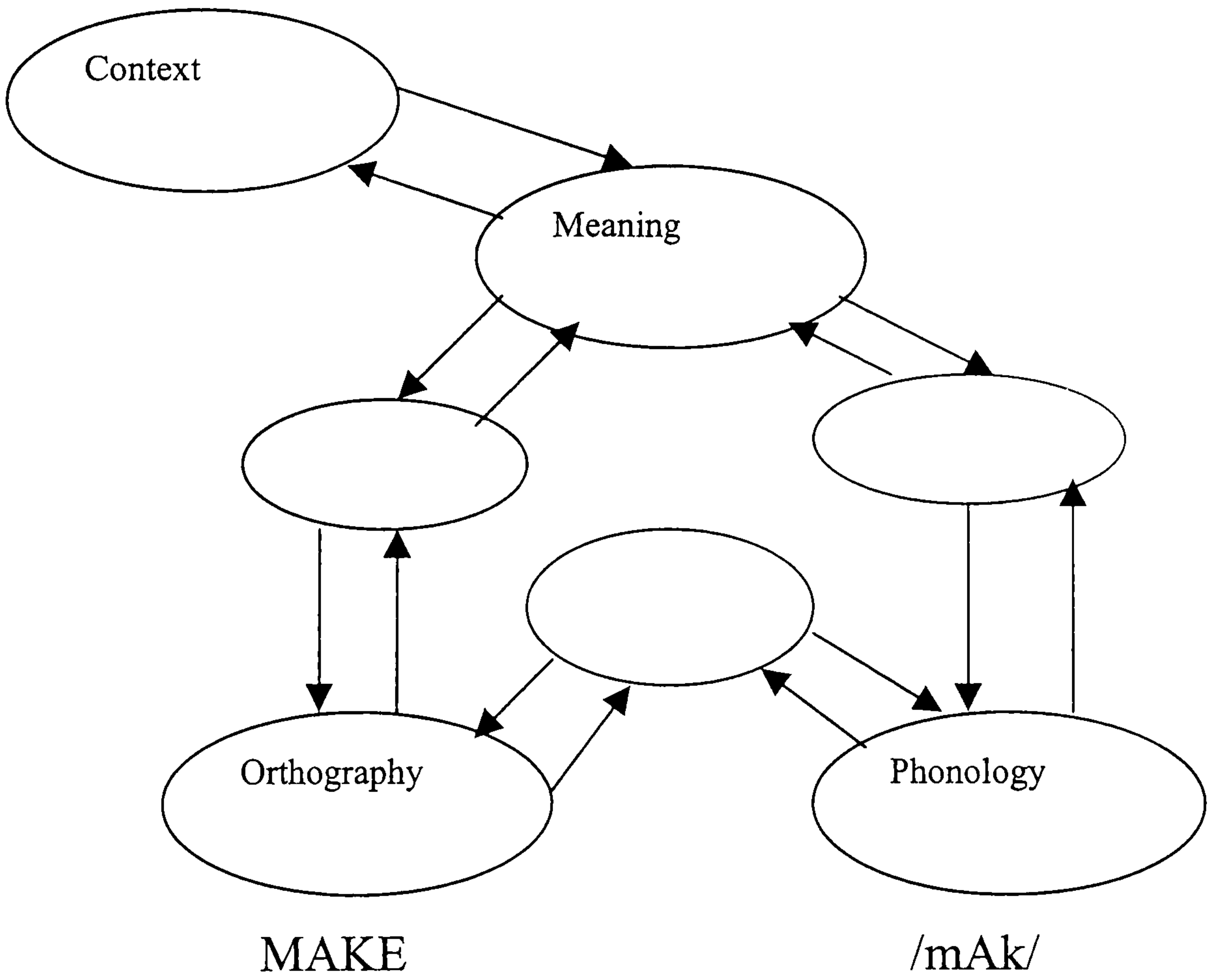

Figure 1.7 The levels of processing in the parallel distributed processing model of Plaut et al. (1996). Most words are read by the direct orthography-phonology route in Plaut et al. (1996). In a final simulation they implemented the contribution of semantics to read low frequency exception words.

Reading a word aloud requires the transformation of orthographic patterns into phonological patterns and this is accomplished via the interactions amongst units. The PDP model proposes a single route for word reading labelled 'the phonological pathway' (Plaut, 1997) in which orthographic representations directly activate their phonological representations. In the PDP model generated by Plaut et al. (1996) spelling to sound correspondences were represented in such way that letters and phonemes within vowels and consonant clusters almost always activated the same units regardless of the context word. It was found that using these representations the model could pronounce all words upon which it was trained correctly, was able to show the frequency-consistency interaction effect traditionally found in skilled readers, and was successful at nonword reading. These results were obtained without the need of a semantic pathway. Once it was demonstrated that word and nonword reading could be successfully accomplished by a single orthographic-phonological route, in a final simulation Plaut et al. (1996) introduced a semantic pathway in the model. The semantic pathway implemented the correct reading of homographs, the reported contribution of imageability in word reading, and the reading outcome of surface dyslexics who exhibit a poor reading of low-frequency exception words. It was assumed that the contribution of the semantic route is required for the correct reading of low frequency exception words whereas the phonological pathway is most competent at reading high frequency words and words with consistent letter to sound correspondences.

1.5.3 Factors affecting word naming

The type of word attributes that affect the speed and accuracy of reading words aloud has been extensively investigated. The outcome of these studies provides data that is necessary to take into account at the time to develop a comprehensive theory of word reading.

The frequency at which words are encountered was perhaps the first word attribute to be studied. Preston (1935) showed that high frequency words were named faster than low frequency words. Some years later, the word frequency effect was revisited by Forster and Chambers (1973) who showed that words were read faster than nonwords and frequent words faster than non-frequent words in immediate word naming. Since then the word frequency effect has been repeatedly reported (Berry, 1971; Frederiksen & Kroll, 1976; Monsell, Doyle, & Haggard, 1989) and it has been demonstrated to affect word reading times even when other variables such as number of orthographic neighbours (N), age of acquisition (AoA), and imageability, have been taken into account (Gerhand & Barry, 1998; Monaghan & Ellis, 2002a; Morrison & Ellis, 2000; Strain, Patterson, & Seidenberg, 1995).

Another word property that has also been the object of study is word length. Its effect in word reading times is nevertheless controversial. The number of letters contained in a word has emerged as a significant predictor of word naming times in a number of studies (Butler & Hains, 1979; Forster & Chambers, 1973; Gilhooly & Logie, 1981a). However, Weekes (1997) failed to find any influence of word length once orthographic neighbours, number of friends, and grapheme frequency were accounted for.

The vast majority of studies in word reading have been conducted in English. English is a language endowed with a deep orthographic-phonological system. This is so because the same letter can be pronounced in more than one way depending on the context. These types of correspondences require deep levels of lexical processing and force English readers to learn usual and unusual pronunciations. This regularity-irregularity factor has been investigated as another potential determinant of word-naming times. Spelling to sound regularities in English therefore are not as easy as one-sound one-letter correspondences. Spelling-sound regularities in English have been detected when considering not individual letters but functional spelling units where one phoneme might correspond to more than one letter and preceding and following letters are taking into phonemic consideration (Venezky, 1970). Another way of extracting spelling to sound regularities is looking at families of orthographic neighbours in which the initial letter or sound changes, maintaining constant the letters of the rest of the word. These orthographic families can have consistent pronunciations when all the words in the family rhyme such as 'bell', 'cell', and 'tell', or inconsistent pronunciations when all the words in the family rhyme with the exception of one word such as 'case', 'base' and 'vase', where all rhyme except for 'vase'. Words coming from consistent families are normally considered regular consistent words. Words from inconsistent families but with regular pronunciation are regular inconsistent words and those with the irregular pronunciation are irregular exception words. A number of studies have shown that the regularity of spelling to sound correspondences affects the speed of word reading and interacts with word frequency. Thus, high frequency words will be read equally quickly whether they are regular or irregular. However, low frequency words will be read slower if they are irregular than if they are regular (Andrews, 1992; Brown & Watson, 1994; Monaghan & Ellis, 2002a; Seidenberg, 1985).

A controversial variable in the study of word reading times is imageability. Imageability refers to the ease with which words evoke a mental image. Strain et al. (1995) created a factorial design in which word frequency, imageability and regularity were manipulated. They found that the three factors interacted with low frequency words the most affected by imageability and regularity and low frequency irregular words the most affected by imageability. Thus, the largest word naming times in Strain et al.'s (1995) study were obtained for low frequency, low imageability, and irregular words. Monaghan and Ellis (2002a) in Experiment 4 replicated the imageability effect obtained by Strain et al. (1995). However, imageability ceased to affect word reading times when AoA was entered into the analysis as a covariant. Coltheart, Laxon, and Keating (1988) also failed to find an imageability effect in the word reading times of children and adults though imageability did affect performance of poor readers.

1.5.4 The AoA effect in word reading

AoA has also been found to be a central factor of word naming speed and accuracy. Gilhooly and Logie (1981a) were the first to demonstrate the influence of AoA in word reading. They carried out a study in which 50 volunteers named 100 words. AoA and word length were the only significant predictors of RT. Similarly, Brown and Watson (1987) conducted a multiple regression analysis on the naming times of 416 words. AoA, familiarity, length, and initial phoneme duration emerged as the only significant contributors to the variance on RT. Coltheart et al. (1988) used a factorial design to investigate the role that AoA and imageability exerts on children and adults word reading. They found that nine year olds' reading accuracy and adult reading times were significantly affected by AoA whereas imageability only affected the reading abilities of poor readers.

Many other studies have reported AoA effects on word reading (Brysbaert, Lange, & Van Wijnendaele, 2000; Gerhand & Barry, 1998; Monaghan & Ellis, 2002a, 2002b; Morrison & Ellis, 1995, 2000). All of these studies mentioned above were based on an AoA measure based on the age at which words were first learned in spoken language acquisition. Yamazaki, Ellis, Morrison, and Lambon Ralph (1997) identified two different forms of age of acquisition that exerted significant influences on Japanese-kanji naming speed. One was the age of acquisition of the spoken words represented by the kanji characters; the other was the age of acquisition of the characters themselves. Japanese children start learning to read at the age of 7 years and follow a well structured programme which is common to all Japanese schoolchildren and which dictates the year of schooling in which different kanji characters will be introduced. Hence a language researcher knows with some certainty when different characters will have been learned. The age of acquisition of the Japanese characters exerted a significant influence on naming speed over and above that of the age of acquisition of the words in spoken language in Yamazaki et al.'s (1997) study. The discovery of two AoA effects, one for spoken language and one for written language, lead the authors to suggest two possible locations of the AoA effect, the visual orthographic lexicon and the speech phonological lexicon.

A final study worth mentioning here is that of Morrison, Hirsh, Chappell, and Ellis (2002). Word reading times of young and adult participants were examined in an attempt to test the hypothesis of AoA effects being in fact cumulative frequency effects. Cumulative frequency refers to the total number of times a word has been used or encountered in an individual's life. Morrison et al. (2002) argued that if the AoA influence is due to cumulative frequency then AoA effects should diminish as a person grows older since the proportional difference in terms of word residence time is greater for young adults than for old adults. They did not find a reliable interaction between participant's age (20 years old and 73 years old participants) and the AoA effect. Their results suggested that the AoA effect cannot be reduced to effects of cumulative frequency but are a genuine reflection of the age or order at which the vocabulary is acquired.

1.6 The visual lexical decision task

The lexical decision task has been regarded as the principal task for investigating word recognition or lexical access. The task requires participants to distinguish words from nonwords. The visual stimuli are presented individually. Participants are asked to respond by pressing a key for words and another key for nonwords. The rationale behind the inclusion of nonwords is that participants cannot anticipate what is to follow and therefore are forced to recognise the words of interest. Reaction times (delay between the appearance of the stimuli and participant's response) and/or accuracy are the standard measures subjected to statistical analysis.

1.6.1 Factors affecting lexical decision

The processes involved in recognising words or in distinguishing words from nonwords, as in the lexical decision task, seem to depend on the nature of the words and nonwords to be accepted and rejected respectively. Decisions based on the orthographic familiarity of the words may be taken when nonwords consist of orthographic/ phonological illegal letter strings. If the nonwords are pronounceable and therefore orthographically legal the individual may base his/her judgement on the phonological familiarity of the word, on whether the stimulus has a lexical entry or on whether the input activates a meaning. Finally, when nonwords sound like words, the so-called pseudohomophones, the decision may be taken based on the meaning that the orthographic input generates (Plaut, 1997).

Support for the semantic implication in word recognition is also found in studies demonstrating the influence of semantic factors such as concreteness in lexical decisions (Hell & De Groot, 1998). However, Hell and De Groot's (1998) results could have been confounded with AoA, a factor that was not controlled in the study and that correlates highly with concreteness. Hino and Lupker (1996) addressed the issue of the role of semantic variables in lexical access (or word recognition). They examined the number of meanings or the polysemy effect along with the word frequency effect in a lexical decision task. Experiment 1 consisted of a fully factorial design with polysemy and frequency independently manipulated. They found that both variables exerted a significant influence on decision latencies, though their stimuli sets were not matched on AoA. Hino and Lupker (1996) interpreted these results utilising the theory behind parallel distributed processing models (Seidenberg & McClelland, 1989; Plaut & McClelland, 1993). The partial activation of word-level units (orthographic and/or phonological units) sends activation to the semantic level units before the word level unit has reached its threshold. In turn the semantic level units send back activation to the word level units. This extra semantic activation facilitates the target word reaching its activation threshold. The cascading activation from the semantic units is greater for polysemic words than for unambiguous words because of the summation of activation from several semantic units.

The frequency effect found by Hino and Lupker (1996) in a lexical decision task has been widely documented, with high frequency words tending to be identify as words faster than low frequency words (Butler & Hains, 1979; Frederiksen & Kroll, 1976; Gilhooly & Logie, 1982; Monsell et al., 1989). Initial theories attribute the word frequency effect to the specific processes of word recognition. Models such as Morton's (1969) logogen model, and McClelland and Rumelhart's (1981) connectionist model, placed the influence of word frequency at the level of word recognition. However, this idea was challenged by those who considered word frequency a variable operating at a post-lexical access level. Balota and Chumbley (1984) compared participants' performance in three tasks requiring lexical access. These were a lexical decision task, a word reading task and a category verification task where individuals decided whether or not category exemplars belonged to a previously presented category name. They found differences in the magnitude of the word frequency effect across tasks. Considering that each task should involve a similar lexical access they argued that the large frequency effect found in lexical decision was due, at least in part, to the production stage. Balota and Chumbley's (1984) argument has not been free from debate. Indeed, Monsell et al. (1989) argued that the locus for the word frequency effect rests on the lexical identification process itself that is well captured by the lexical decision task.

Whether the frequency effect arises from lexical or post-lexical access is out of the scope of this thesis. For the moment it suffices to emphasise that word frequency plays a role in lexical decision tasks.

Reported evidence has also shown that lexical decision latencies are affected by other variables such as concreteness with concrete words being recognised faster than abstract words (Schwanenflugel & Shoben, 1985) and word length with faster recognition latencies for short than for long words (Gilhooly & Logie, 1982).

1.6.2 The AoA effect in lexical decision

A number of early studies examining the role of AoA in word recognition tasks such as lexical decision, auditory or visual recognition thresholds failed to find any trace of the effect on word identification. Gilhooly and Logie (1981b) conducted two experiments using tachistoscopic visual thresholds. They looked at the factors affecting the time of visual exposure necessary to recognise 100 words. Word length and frequency but not AoA effects were observed. Gilhooly and Logie (1981b) carried out a similar study based on auditory rather than visual recognition. The results showed that while frequency and familiarity affected recognition, AoA did not. Gilhholy and Logie (1982) reported the results of a visual lexical decision study in which 36 volunteers distinguished 100 words from 100 pseudowords or nonwords. Imagery, AoA, familiarity, concreteness, ambiguity, length, and word frequency were entered into a simultaneous regression analysis. Length, frequency and word familiarity were the only significant predictors of decision latencies. The consistent absence of an AoA effect in word identification tasks lead Gilhooly and Watson (1981) to abandon the idea of AoA affecting lexical access processes. Instead they postulated a phonological location for the AoA effect represented by an exit logogen system.

Nevertheless, subsequent research has shown the opposite results. These studies, mainly based on the lexical decision task, have repeatedly reported AoA effects. Lyons, Teer, and Rubenstein (1978) in an early study found AoA effects in the recognition of tachistoscopically presented words. They used a semi-factorial design in which AoA was independently manipulated, with 22 early acquired words and 22 late acquired words, and word frequency experimentally controlled. Butler and Hains (1979) considering the limitations of factorial designs (small samples of words and limited range of values in each variable) chose a multiple regression analysis in their approach to the study of word recognition. They found that AoA, frequency and length, were the main predictors of lexical decision latencies. Cirrin (1984) found that word frequency and AoA significantly affected lexical decision latencies for children (age 6) and adults. Morrison and Ellis (1995) examined the effects of word frequency and age of acquisition on written word recognition. Experiments 5 and 6 involved two lexical decision tasks (one manipulated AoA, one manipulated word frequency). They found a significant difference of 54ms between high and low frequency words. Importantly, the 66ms difference between early and late acquired words was also significant. They concluded that AoA and frequency made independent contributions to lexical decision speed. Turner, Valentine, and Ellis (1998) also found AoA effects in visual and auditory word recognition.

Considering the enormous amount of debate that the AoA and frequency effects have generated with respect to their importance and location, Gerhand and Barry (1999) designed a series of experiments in which AoA and frequency were orthogonally manipulated in fully factorial designs. Fully factorial designs allow the observation of interactions between variables. Gerhand and Barry (1999) observed an interaction between word frequency and AoA in lexical decision latencies with AoA affecting decision speed of low frequency words but not of high frequency words. They interpreted these findings as the result of different locations for the frequency and AoA effect. Thus, while frequency operates at the level of lexical access AoA exerts its influence at the post lexical level of phonology. Lexical access of high frequency words occurs rapidly and the decision may be made at the level of the orthographic representation. Low frequency words, however, activate their orthography more slowly allowing a cascade activation of their phonology where the more 'complete' early acquired words will be recognised faster than the late and not so 'complete' words.

In summary, it has been widely documented that AoA affects lexical decision times. The initial failure to find the effect has been suggested to be due to the correlation of AoA with other variables and the problems that highly associated variables cause in multiple regression analysis techniques (Morrison & Ellis, 1995). All of the recent studies, either based on factorial designs or multiple regression, have reported AoA effects on lexical decision tasks and this has been shown whether objective or rated AoA measures were used (Bonin, Chalard, Meot, & Fayol, 2002; Colombo & Burani, 2002; Gerhand & Barry, 1999; Morrison & Ellis, 2000).

1.7 Theoretical accounts of the mechanisms and loci of AoA effects

1.7.1 Single locus

1.7.1.1 The logogen model

Gilhooly and Gilhooly (1979) proposed an account of AoA based on the logogen system postulated by Morton (1969). In the earliest version of the logogen system, the representational units or logogens hold the phonological and orthographic information for each word. Gilhooly and Gilhooly (1979) reasoned that the AoA effect arises from the different activation thresholds held by early and late acquired words. They stated that late acquired words are learnt by means of definitions consisting of early acquired words. This process is likely to create a certain association for which the activation of a late acquired word will partially activate related early acquired words. This constant priming will result in lower activation thresholds for early acquired words than for late acquired words.

Along the same lines but more specific regarding the location of the AoA effects is Gilhooly and Watson's (1981) proposal. Once again they based their argument on the logogen model, but this time on a revised version (Morton, 1979; Morton & Patterson, 1980). The revised logogen model postulates separate input and output logogen systems. Considering the evidence to date of AoA effects in production but not in word recognition tasks, Gilhooly and Watson (1981) situated the effect in the exit logogen system or speech output system.

1.7.1.2 A phonological locus

Brown and Watson (1987) proposed the "phonological completeness hypothesis" to account for the AoA effects. Their study of which factors affected word reading showed that word learning age was a better predictor of word naming times than spoken or written word frequency. They assumed like their predecessors (Gilhooly & Gilhooly, 1979; Gilhooly & Watson, 1981) that AoA only has reliable effects on word production and therefore the effect had to be located in the production system. They hypothesised that early acquired words differ from late acquired words in the quality of their phonological information in the phonological output lexicon. They argued that children have a less economical use of the storage space and therefore store early acquired words as wholes which are kept as complete units during adult life. A different strategy is adopted for late acquired words. Since the storage space is limited as the vocabulary grows, late acquired words are not directly represented. This creates a processing cost since late acquired words have to be generated each time they need to be produced whereas early acquired words are always ready for production.

Although the completeness hypothesis offers a comprehensive account for the AoA effects, Monaghan and Ellis (2002b) failed to find evidence to support it. They argued that if early acquired words are stored in a holistic phonological form and late acquired words have a more fragmented phonological representation, then it should take less time to segment the sounds of late acquired words than to segment the sounds of early acquired words. In their experiment, participants segmented words on the initial consonant cluster, at the onset-rime level of the word and at the syllable boundary. AoA was found to affect only segmentation at the consonant cluster with early acquired words being segmented faster than words acquired later. The direction of the effect was the opposite of that predicted by the completeness hypothesis.

A number of authors have also proposed the phonological output as the source of AoA effects. Unlike Brown and Watson (1987), however, these studies do not mention how exactly the AoA effect works. Morrison and Ellis (1995) suggested the access to the phonological representations as the locus from which AoA effects emerge. They supported this assumption based on the reported evidence of AoA effects in object naming and immediate word naming but not in delayed naming. Findings of AoA effects in lexical decision tasks were interpreted as an automatic activation of the phonology in the process of deciding whether or not a letter string is a word.

Gerhand and Barry (1999) carried out five experiments consisting of lexical decision tasks. The degree of reliance on phonology to complete the tasks correctly was manipulated. They reasoned that if AoA emerges from the phonological representations the effect would be reduced when participants could distinguish words from nonwords without consulting the word's phonology. In Experiment 2 words and orthographically illegal nonwords were presented as stimuli material to perform a lexical decision task. It was argued that in this case participants could recognise the words based on their orthographic familiarity without the need to check on the phonology of the word. The AoA effect was reduced in Experiment 2. Gerhand and Barry (1999) concluded that the AoA effect is located in the retrieval of lexical phonology.

1.7.1.3 A lemma locus

Gerhand and Barry (2000) conducted a single case study whose results lead them to argue against a phonological location for the AoA effect. Instead they suggested that the effects of AoA emerge from the lemma representations that refer to an intermediate level between the conceptual system and the phonology. They investigated the semantic errors produced in a word reading task by LW, a deep dyslexic patient. AoA emerged as a significant predictor of accuracy since more early than late acquired words were read correctly. In addition, the semantic errors generated by LW were consistently earlier than the target word. Assuming two stages of speech output - the lexemes representing phonological forms and the lemmas as an intermediate level between the conceptual system and the phonology - Gerhand and Barry (2000) proposed a lexical location for the AoA effect situated at the lemma level since there is no reason to think that lexeme's properties should affect the production of semantic errors.

1.7.1.4. A semantic locus

Brysbaert, Van Wijnendaele, and De Deyne (2000), inspired by a study carried out in Dutch by Van Loon-Vervoon (1989), explored the influence of AoA in two semantic tasks: a word association task and a semantic classification task. They replicated the results obtained by Van Loon-Vervoon (1989), finding longer reaction times to produce associates to low frequency and low imageability words that were acquired late. It was also demonstrated that AoA and word frequency affected a semantic categorisation task in which overt naming was not required. In the light of these results they suggested a semantic locus for the AoA effect. Brysbaert, Van Wijnendaele et al. (2000) argued that consistent with their results are the high correlations normally found between AoA and a semantic variable such as imageability. They also mentioned that the robust AoA effects normally found in picture naming are due to the semantic requirement of the task.

Lyons et al. (1978) also suggested the semantic system as the possible loci for the AoA effect when they stated " if we think of words as representing concepts, then the implication of the independent operation of age-at-acquisition underscores this relationship between when a child learns a certain concept and its availability to him or her in later life" (p. 186).

1.7.2 Multiple loci

Yamazaki et al. (1997) were perhaps the first authors to suggest multiple loci for the AoA effect. They carried out a word naming experiment where participant's were asked to read Japanese kanji words. Two AoA variables along with other seven relevant variables were entered into a multiple regression analysis. These were the AoA of the spoken word form and the AoA of the written word from. Both emerged as significant predictors of word reading times. Yamazaki et al. (1997) suggested that the speech output lexicon and the visual input lexicon were responsible for the spoken and written AoA effects respectively.

Ellis and Lambon Ralph (2000) offered another account for the AoA effect based on the performance of a connectionist network. They argued that the effect rests on the connections between representations. They trained the network in a cumulative interleaved manner and through a series of simulations showed that the model performed better, with reduced error, for early than for late entered patterns. Of particular importance is simulation 4 in which they tested whether AoA is the result of cumulative frequency. Cumulative frequency had been put forward a number of times as a tentative explanation of the AoA effect (Carroll & White, 1973b; Lewis, 1999). Ellis and Lambon Ralph (2000) in simulation 4 trained the network with 100 early patterns that were presented once per epoch during 1000 epochs after which they introduced 100 late patterns that were presented twice in the subsequent 1000 epochs. In consequence, at the end of 2000 epochs early and late entered patterns had been trained the same number of times. The results showed a significantly better performance for early entered patterns than for late entered patterns supporting the notion that AoA effects are not reducible to cumulative frequency.

As to how the AoA effects occurs, Ellis and Lambon Ralph (2000) hypothesised that the plasticity decline resulting from the prior training with early entered patterns is the cause of a decrease in the performance of late entered patterns. A similar loss in plasticity would cause the formation of more efficient connections for early than for late acquired words explaining the AoA effects in human lexical processing. According to Ellis and Lambon Ralph (2000), the AoA effect is not confined to lexical processing, but would affect any representations acquired in a cumulative and interleaved manner, consequently it would have to be observed in verbal and non-verbal tasks. In support of this idea AoA effects have indeed been found in verbal (Gerhand & Barry, 1998; Morrison et al., 1992) and non-verbal tasks such as familiarity decision to faces (Lewis, 1999; Moore & Valentine, 1999).

1.8 Organisation of the thesis

The initial aim of the present thesis was the examination of the AoA effect in a second language acquired once the native and first language has been consolidated. These particular individuals, late or dominant bilinguals, hold a specific language configuration of scientific interest by itself but more importantly they constitute an ideal group to test whether or not the AoA effect roots in a particular word learning age or critical period.

One of the main implications deriving from the demonstration of a significant effect of AoA on second language word processing is the assurance that AoA effects are not due to a critical period where brain's plasticity is high. Instead the order of word acquisition is the cognitive organisational principle relevant to word processing of languages acquired at any age. Another obvious implication is the need for the control of the AoA variable in bilingual studies of word processing and its implementation in bilingual models.

Chapter Two consists of two pilot experiments carried out in English and Spanish as first languages. These experiments were a first approach to the AoA effect in the two languages mastered by the bilinguals that participated in the experiments. The same two languages will be considered through the current thesis. The finding of an AoA effect in Spanish and English as native languages will serve as a baseline for the examination of the effect in a second language.

In Chapter Three AoA and word frequency ratings for English as a second language acquired in adulthood were collected. An investigation of the possible AoA influence in L2 (English) and in L1 (Spanish) was then conducted in an object naming task and a lexical decision task where AoA was orthogonally manipulated. This manipulation involved two sets of translation equivalent pairs that were either early or late acquired in both languages.

It is possible to argue that second language words inherit somehow the AoA values of their translation equivalents in the first language. Chapter Four set out to investigate whether the AoA of the first and second language are independent variables. Lexical decision latencies were collected and entered into a multiple regression analysis to assess the predictable values of the first and second language AoA variables. A second experiment was created with a fully factorial design in which language and AoA were independently manipulated.

Chapter Five considers the theoretical account for the AoA effect proposed by Ellis and Lambon Ralph (2000) in which it is stated that AoA effects are likely to be observable in tasks that require a knowledge acquired in a cumulative, interleaved manner and where the connections between representations are of an arbitrary nature (as the link between an object and its name). The experiments involved word reading tasks completed in Spanish, a language with a shallow orthography-phonology system, and in English, a language with a deep relation between spelling and sounds. According to Ellis and Lambon Ralph, an interaction between language and AoA will be observable with AoA affecting perhaps the reading times of English words but not the reading times of Spanish words.

Chapter Six examines the AoA effect in translation judgement tasks where the comprehension of the word is inevitably required. In addition to assessing the AoA effect in word comprehension, Chapter Six also investigates the semantic nature of the AoA effect. It was assumed that the semantic representations are shared between the two languages of a bilingual. If the AoA effect emerges from the semantic representations due to the order of 'meanings' acquisition then early acquired first language words will be translated faster than late acquired first language words regardless of the AoA values of the words in the second language. This hypothesis was tested with fully factorial designs where language and AoA are orthogonally manipulated.

Finally Chapter Seven will summarize the findings observed through all the experiments presented in the previous chapters. The main conclusions regarding AoA effects in second and first languages will be provided along with a discussion of the effects observed related to the main theories of AoA and principles of bilingual lexical configuration.

CHAPTER TWO

AoA EFFECTS IN FIRST LANGUAGES: A FIRST APPROACH.

2.1 Introduction

Chapter One reviewed those studies that have previously investigated the factors affecting word recognition. Through this research much insight has been gained on what and how different word attributes govern the processes of word identification or lexical access. One essential factor reported to affect word recognition processes is the age at which words are acquired (AoA). Most of the research focused on the AoA effect in word recognition has been conducted in English although AoA effects have been recently reported in word identification in French (Bonin et al., 2002) and in Italian (Bates, Burani, D'Amico, & Barca, 2001; Colombo & Burani, 2002).

Chapter Two presents two pilot experiments in which native speakers of English and Spanish distinguished English and Spanish words from nonwords that were orthographically legal in English and Spanish respectively. Both experiments were based on a semi-factorial design in which AoA was subjected to an orthogonal manipulation while controlling for word frequency and object familiarity.

It is important to mention here Raaijmakers, Schrijnemakers, and Gremmen's (1999) recent paper. They evaluated the use of by-items analysis in factorially designed experiments where one factor is manipulated and other factors are controlled. Raaijmakers et al. (1999) discussed the consequences that Clark's (1973) critique of statistical procedures in language and memory studies have had on the way such analyses have been carried out ever since. Clark (1973) pointed out that the randomly selected stimulus words used for experimentation increased the probability of Type I errors. The experimenter could conclude that the factor under observation had an effect when the effect would be due in fact to differences on other factors that the random selection of items does not control for. Raaijmakers et al. (1999) explained that the error that occurs by the random selection of items could be solved using statistical or experimental procedures. Statistical control is gained by adding the item variance to the analysis conducting by-items analysis. Experimental control is gained by matching the experimental items on those variables that correlate highly with the dependent variable.

Experimental control is the approach that has been taken for this study. According to Raaijmakers et al. (1999) taking into account by-items analysis when items are controlled for increases the probability of Type II errors. Therefore analysis by items will be reported, but emphasis will be placed on the by-subjects analysis.

2.2 Experiment 1 – AoA in English as a first language

2.2.1 Method

2.2.1.1 *Participants*

The participants were 20 native speakers of English (15 females and 5 males) with a mean age of 20 years (range 18-24). At the time of testing, all the participants were students at the University of York, England. They received a course credit for their participation. None of them reported being bilingual.

2.2.1.2 *Materials*

The experimental materials were 64 stimuli, 32 concrete nouns and 32 nonwords. The list of words consisted of 16 early acquired and 16 late acquired words. Nonwords were created from real words by changing one or two letters in such a way that the nonword remained orthographically legal for example 'bing' or 'tox'. The list of nonwords was derived from a list of words different to those used as experimental items. Words were matched for word frequency, a combined measure for written and spoken English (Celex: Baayen, Piepenbrock, & Van Rijn, 1993), and object familiarity (Morrison et al., 1997). AoA ratings were based on a 7-point scale (Morrison et al., 1997). Early acquired words had a rating of 2.10 or below (approximately before the age of 3) and late acquired words had a rating of 2.15 or above (approximately after the age of 3). Mean, standard deviation and range of values for each variable are shown in Table 2.1. The word sets used in Experiment 1 are shown in Appendix 1.

Stimulus set		AoA	Log Frequency	Object Familiarity
Early acquired	M	1.74	1.29	3.47
	S	0.29	0.43	0.94
	Range	1.30-2.10	0.60-1.93	2.09-4.68
Late acquired	M	2.57	1.25	3.33
	S	0.35	0.53	0.67
	Range	2.15-3.45	0.48-2.20	2.50-4.68

Table 2.1 Mean (M), standard deviation (S) and range of values for the variables controlled for in Experiment 1. Note: AoA = Age of acquisition.

2.2.1.3 *Procedure*

The experiment was carried out on an Apple Mac Centris 660-AV computer screen in black 48 lowercase print using New York font. The screen was at a comfortable reading distance for each participant. The order of presentation of items (words and non-words) was randomised for each participant. Each trial started with a 1-second fixation dot followed immediately by the stimulus word or nonword that remained on the screen until the participant made a response, whereupon the fixation dot reappeared. Participants were instructed to decide as quickly and as accurately as possible if the stimulus item was a word or a nonword. They pressed the B key for words and the N key for nonwords on a standard keyboard. Twenty practice items (10 words and 10 nonwords) were presented at the start of the experiment. Presentation of items and recording of reaction times was done using the SuperLab experiment generator package (Abboud, 1991).

2.2.2 Results

Only reaction times to correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Thus, fourteen responses (2.18%) that fell outside 3.5 standard deviations were removed. A further 22 responses (3.43%) were removed because of errors. Table 2.2 shows the mean naming RT and error percent in each condition.

		Early acquired	Late acquired
RT	M	546	580
	S	31	33
% error		2.18	4.68

Table 2.2 Mean RT (M), standard deviation (S) and percent errors (% errors) for early and late acquired items in Experiment 1.

2.2.2.1 *Reaction time and error analyses*

A t-test analysis was carried out to compare mean reaction times. The difference between early and late acquired items was significant in the analysis by subjects, $t_1(19) = -3.81$, $p<0.001$, and in the analysis by items, $t_2(15) = -3.49$, $p<0.05$, with early acquired words being identified as words faster than later acquired words.

Since experimental items were not matched on imageability this variable was covariated to assess its contribution to English decision times. In Experiment 1 the t-test analysis of items showed a main effect of AoA. When imageability was entered as a covariate the AoA effect was still significant, $F_2(1,32) = 7.73$, $MSE = 10049.92$, $p< 0.05$. However, imageability was not significant, $F_2(1,32) = 1.00$, $MSE = 1300.79$, $p > 0.1$.

Analysis of errors was computed using the Wilcoxon matched-pairs signed-ranks test. The different accuracy between early and late acquired words approached significance, $Z = -1.73$, $p=0.08$, with a trend towards higher accuracy for early than for late acquired words.

The mean reaction time for rejecting nonwords was 688ms with 5.01 % errors.

2.2.3 Discussion

The AoA effect was observed in an English lexical decision task completed by native English speakers. This is very much in line with the findings of English word recognition (Butler & Hains, 1979; Nagy, Anderson, Schommer, Scott, & Stallman, 1989; Morrison & Ellis, 1995) where it has been well established that early acquired words are recognised faster than late acquired words. An analysis of covariance showed that the AoA effects found in Experiment 1 were not confounded with imageability effects.

2.3 Experiment 2 –AoA in Spanish as a first language

2.3.1 Method

2.3.1.1 *Participants*

The participants were 20 native speakers of Spanish (11 females and 9 males) with a mean age of 26 years (range 24-33 years). Participants were studying at the University of York, England. They were dominant bilinguals with English as a second language learnt after a mean age of 10 years (range 8-15 years). They received a course credit for their participation [1].

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[1] Some Spanish subjects participated in more than one experiment reported in the present thesis. However, the length of time between experiments was a minimum of four weeks.

2.3.1.2 *Materials*

The stimulus words were 32 Spanish object names taken from Cuetos, Ellis, and Alvarez (1999). Half of the words were early acquired and half late acquired words and they were the translation equivalents of the stimuli used in Experiment 1. Thirty-two nonwords were created from real words by changing one or two letters in such way that the nonword remained orthographically legal in the Spanish language as for example 'cuabro' or 'sibla'. Nonwords were created from different words to those used as experimental items. Words were matched for written frequency from Alameda and Cuetos (1995) and object familiarity from Cuetos et al. (1999). AoA ratings were based on an 11-point scale (Cuetos el al., 1999). Early acquired words had a rating of 3.91 or below (approximately learnt at the age of 3 or before) and late acquired words had a rating of 4.08 or above (approximately learnt at the age of 4 or later). Mean, standard deviation and range of values for each variable are shown in Table 2.3. The word sets used in Experiment 2 are shown in Appendix 2.

Stimulus set		AoA	Frequency	Object Familiarity
Early acquired	M	3.49	1.29	3.40
	S	0.31	0.44	1.09
	Range	3.00-3.91	0.70-2.05	1.86-4.75
Late acquired	M	4.61	1.34	3.29
	S	0.36	0.47	0.79
	Range	4.08-5.16	0.70-2.28	2.04-4.72

Table 2.3 Mean (M), standard deviation (S) and range of values for the variables controlled for in Experiment 2. Note AoA = Age of acquisition.

2.3.1.3 *Procedure*

The procedure was the same as in Experiment 1. Participants were first shown 10 words and 10 nonwords for practice followed by the experimental items where they press the B key if they considered the item to be a word and the N key if they judged the item to be a nonword.

2.3.2 Results

Only correct responses that fell within 3.5 standard deviations of the mean of reaction times were analysed. Ten responses (1.56%) that fell outside 3.5 standard deviations were removed from the analysis.

Twelve additional responses (1.87%) were errors that involved pressing the wrong response key. Table 2.4 shows the mean RT, standard deviations and error rates.

		Early acquired	Late acquired
RT	M	604	634
	S	55	76
% error		1.25	2.5

Table 2.4 Mean RT (M), standard deviation (S) and percent errors (% errors) for early and late acquired items in Experiment 2.

2.3.2.1 ***Reaction time and error analyses***

The difference between early and late acquired items was significant in the analysis by subjects, $t_1(19) = -2.37$, $p<0.05$, and in the analysis by items, $t_2(15) = -2.57$, $p<0.05$, with early acquired words being identified as words faster than later acquired words.

Since experimental stimuli were not matched on imageability this variable was covaried to assess its contribution to Spanish decision times. In Experiment 2 the t-test analysis of items showed a main effect of AoA. When imageability was entered as a covariate the AoA effect was still significant, $F_2(1,32) = 4.45$, $MSE = 8021.01$, $p< 0.05$. However, imageability was not significant, $F_2(1,32) = 0.002$, $MSE = 1990.60$, $p > 0.1$.

Analysis of errors was computed using the Wilcoxon matched-pairs signed-ranks test. The difference between early and late acquired words regarding accuracy was not significant, $Z = -1.19$, $p=0.23$.

Nonwords were rejected at an average time of 756ms with an error rate of 3.1 %.

2.3.3 Discussion

The AoA effect in Spanish in Experiment 2 is the first demonstration of such an effect in lexical decision for Spanish but echoes the similar results found with native speakers of English (Butler & Hains, 1979; Gerhand & Barry, 1999; Morrison & Ellis, 1995, 2000). Early acquired words in Spanish as a first language are recognised faster than words acquired some time later. The AoA effect found in Spanish also suggest that AoA is a universal word attribute not only restricted to English language.

The sizes of the AoA effects for English decision times (34ms) and Spanish decision times (30ms) were compared by transforming the mean rating for early and late acquired words into months. Early and late acquired words in Spanish corresponded to a mean time of 42 and 55 months and in English to a mean time of 21 and 31 months respectively. On the basis of this, a time interval for the acquisition of the Spanish and English words of 13 and 10 months respectively was calculated. The AoA effect found in Spanish (30ms) and English (34ms) decision times was then divided by the time interval of word acquisition. From this the size of the AoA effect in each language per estimated month. The AoA effect was slightly larger in English (3.40 ms/month) than in Spanish (2.31 ms/month).

2.4 General Discussion

Experiments 1 and 2 were two pilot experiments designed to test the AoA effect in English and in Spanish as first languages. The results show that AoA affects the lexical decision times of English and Spanish native speakers. These results are consistent with previous studies on the factors affecting word recognition where it has been demonstrated that AoA plays a key role (Butler & Hains, 1979; Gerhand & Barry, 1999; Morrison & Ellis, 1995, 2000). All of the studies, however, have been looking at AoA in native languages. This evidence along with the definition of the AoA effect itself, words acquired early in life are recognised and produced faster than words acquired some time later, may lead to the conclusion that the age at which the vocabulary is acquired determines the organisation of words in mind. If this is the case, no AoA effect will be observable in a second language acquired after early childhood. This is the question addressed experimentally in Chapter Three.

CHAPTER THREE

DO AoA EFFECTS OCCUR IN SECOND LANGUAGES?

3.1 Introduction

Two pilot experiments in Chapter One indicated that AoA exerts an influence on the lexical processing of English and Spanish as first languages. In Chapter Three the age of acquisition (AoA) effect was investigated in the first (L1) and second (L2) language of Spanish – English dominant bilinguals in an object naming and a lexical decision task.

The majority of studies of AoA effects, like the majority of studies of language processing in general, have been conducted in English, but AoA effects have now been reported for picture naming in Spanish (Cuetos et al., 1999) and French (Kremin et al., 2000), for word naming in Dutch (Brysbaert, Lange et al., 2000) and Italian (Bates et al., 2001) and for the naming of Japanese kanji characters (Yamazaki et al., 1997). All of these studies have, however, involved participants operating in their native first languages. Hence, the AoA effects observed have typically involved comparisons between words learned in early childhood and words learned in later childhood or adulthood. During those early childhood years, described by some theorists as a 'critical period' for language acquisition, major neurological changes occur in the brain of the growing child. These changes take place when early vocabulary is being learned and they may be linked in a variety of ways to the process of native language acquisition (Bates, Thal, & Janowsky, 1992).

It is conceivable that the AoA effects revealed in adults operating in their native languages reveal differences in the quality of lexical representations acquired during or after the period when those developmental neural processes are occurring. The aim of the present Chapter is to test if the AoA effect is a consequence of age and maturational constraints or is a consequence of the order at which vocabulary is learnt.

Bilinguals who participated in the experiments presented in Chapter Three (and throughout the rest of the thesis) were all native speakers of Spanish who had spent their childhood in Spain. Their first contact with English had been at around the age of 11. In terms of the standard nomenclature for characterising different types of bilingual they would all be termed 'dominant' Spanish-English bilinguals. Dominant bilinguals are those who master two languages with different levels of proficiency in each. One of the two languages, usually the mother tongue, is the dominant language whereas the other is their second language in which they are competent but not at a native speaker level. The most frequent cause for this unbalance in fluency is a 'late' starting point in the acquisition of the second language.

It is possible to investigate AoA effects in the second as well as the first language of such people because there are some words that Spanish students learning English tend to be taught early and other words whose introduction is delayed until later (just as there are words which native speakers of Spanish or English typically learn early in childhood and other words whose acquisition is generally later). The present Chapter will also present the data collection of word frequency and AoA ratings for English as a second language along with their validity when compared with normative data.

In Experiment 3, dominant Spanish-English bilinguals named pictures of familiar objects whose names were early or late acquired in both Spanish as a first language and English as a second language. The word sets were matched for frequency of occurrence in both Spanish and English; also on name agreement, object familiarity and word length. Experiment 4 was similar in conception to Experiment 3, but this time participants carried out lexical decision tasks in which they were required to distinguish words that are early and late acquired in both English and Spanish from stimuli that are nonwords in both languages.

3.2 Collection of AoA and Frequency ratings for English as a second language

3.2.1 AoA in English as a second language

AoA ratings for English as a second language were obtained for 132 words selected from Cuetos et al. (1999). The words were the names of 132 Snodgrass and Vanderwart (1980) pictures and were chosen on the basis that the items had single-word names in both Spanish and English and would be familiar to speakers in both countries and languages.

Twenty-eight Spanish native speakers with a mean age of 25 years (range 20-33 years) generated the ratings. None had experienced a bilingual environment during childhood. The mean age at which raters started to learn English was 11 years (range 7-14 years). They had been learning English for a mean period of 10 years (range 6-17 years) and had been living in England a mean time of one year (range 4 months – 3 years). They were asked to rate the 132 English object names according to when they believed they first learned those words in English as a second language. The words were rated, following Gilhooly and Logie's (1980) methodology, on a seven-point scale running from 1 = learned in the first year as an English language learner, through 2 = learned in the second year as an English language learner, to 7 = learned in the seventh year as an English language learner or later. An additional option on the rating scale titled N.A. was created to allow raters to indicate that they had not yet learned that word in English. The ratings of five raters who were unfamiliar with more than 15 of the English words were discarded, so the final ratings were based on 23 raters. The ratings on the 1 to 7 point scale were converted into estimated months from the point at which the raters started leaning English. Most words obtained a value between 12 months and 84 months.

One hundred and two of the words were found in the vocabulary lists of two textbook series used in Spain to teach English as a second language (Beaven, Soars, & Soars, 1984; Walker, 1983). For each series, words listed as to be taught within the first year of learning English were assigned a value of 12 months, words listed as to be taught in the second year were assigned a value of 24 months, and so on up to values of 48 months. For each word the values for the two book series were then averaged to create an objective AoA measure for English as a second language. That objective measure correlated 0.62 with the ratings for acquisition in English as a second language. This is similar to other correlation reported for objective and rated measures of AoA for native speakers (Carrol & White, 1973a; Gilhooly & Gilhooly, 1980; Morrison et al., 1997).

3.2.2 Word frequency in English as a second language

Another group of 24 Spanish native speakers rated 132 object names for the frequency in which they encountered or used. The mean age of the raters was 26 years (range 20-33 years). The mean age at which they had begun to learn English was 10 years old (range 7-14 years) and they had been learning English for a mean period of 16 years (range 9-24 years). At the time of the ratings, the participants had been living in England for a mean time of 2 years and 1 month (range 4 months – 4 years). Raters were asked to estimate how often they used or encountered each word in conversation or print on a 7-point scale ranging from 1 = about once a year through 2 = every few months to 7 = more than 5 times a day. An additional box was created for those words with which raters were unfamiliar in English. Thirteen words were removed because fewer than 75% of participants knew the word, leaving 119 words. The correlation obtained between rated frequency in English as a second language and objective frequency in English language samples was 0.51 for the comparison with the Celex (Baayen et al., 1993) frequency count and 0.57 for Hofland and Johansson (1988) frequency count. These correlations are in the same range as the correlation obtained by Morrison et al. (1997) between frequency rated by native speakers of English and the same objective measures (0.48 and 0.55 respectively). The ratings for frequency in English as a second language correlated 0.89 with the ratings reported by Morrison et al. (1997) for native speakers of English, suggesting that the language experiences of the two groups are similar and that objective frequency counts of English are adequate for use with second language speakers of English resident in England. Table 3.1 shows the correlation between the AoA and word frequency measures in English as a first and as a second language.

	1	2	3	4	5	6
1 Rated frequency (L1)	1	0.89	0.48	0.55	-0.55	-0.49
2 Rated frequency (L2)		1	0.51	0.57	-0.64	-0.57
3 Celex frequency (L1)			1	0.82	-0.48	-0.39
4 H & J frequency (L1)				1	-0.52	-0.41
5 Rated AoA (L2)					1	0.62
6 Objective AoA (L2)						1

Table 3.1 Correlation matrix between AoA and word frequency measures in English as a first language (L1) and as a second language (L2). Note: H & J = Hofland and Johansson, AoA = Age of acquisition.

3.3 Experiment 3 – Picture naming and AoA

3.3.1 Method

3.3.1.1 *Participants*

Twenty-two native speakers of Spanish (11females and 11 males) with a mean age of 25 years (range 20-33 years) participated in Experiment 3. All of them had spent their childhood in Spain and the mean age at which they first began to learn English was 11 years old (range 7-16 years). At the time of testing, all the participants were studying at the University of York, England. They had been living in England, using English on a daily basis, for a mean time of 2 years (range 8 months to 5 years).

3.3.1.2 *Materials*

Two sets of 32 items were created that were early or late acquired in both Spanish as a first language and English as a second language. Early acquired in Spanish as a first language equated to an estimated learning age of less than 5 years 8 months while late acquired in Spanish as a first language equated to an estimated learning age of 5 years 9 months or more. Early acquired in English as a second language meant that the word was learned within the first two years of studying English whereas late acquired in English as a second language meant that the word was learned in the third year of studying English, or later. AoA values for Spanish were taken from Cuetos et al. (1999). The early and late sets were matched on the visual complexity of the pictures (from

Morrison et al., 1997), the familiarity of the objects and their name agreement in both Spanish (Cuetos et al., 1999) and English (Morrison et al., 1997), the frequency of the object names in Spanish (Alameda & Cuetos, 1995) and English (Celex Lexical Database: Baayen et al., 1993). Number of syllables was matched within each language since the different length of the Spanish and English words makes it impossible to match word length across languages. Mean, standard deviations and range of values for each variable are shown in Table 3.2. The items and their characteristics are shown in Appendix 3.

Stimulus set		AoA	Frequency	Object Familiarity	Visual Complexity	Name Agree't	No. of Syl's
Early	M	3.55	1.25	3.63	2.35	96.56	2.38
acquired	S	0.29	0.39	0.90	0.88	4.90	0.62
Spanish items	Range	3.12 – 3.98	0.60 – 1.91	2.31 – 4.72	1.14 – 3.41	84 - 100	1 - 3
Late	M	4.66	1.26	3.23	2.23	94.75	2.50
acquired	S	0.31	0.27	0.72	0.57	3.42	0.63
Spanish items	Range	4.12 – 5.06	0.85 – 1.82	2.04 – 4.13	1.08 – 3.19	89 - 100	2 - 4
Early	M	18.48	1.27	3.60	2.34	93.94	1.25
acquired	S	3.93	0.41	0.80	0.82	8.43	0.45
English items	Range	12 - 24	0.48 – 1.91	2.36 – 4.82	1.00– 3.85	70 - 100	1 - 2
Late	M	37.77	1.18	3.18	2.53	94.75	1.56
acquired	S	10.55	0.29	0.51	0.45	8.97	0.51
English items	Range	25.80 – 60.63	0.78 – 1.84	2.50 – 4.09	1.60 – 3.30	77 - 100	1 - 2

Table 3.2 Mean (M), standard deviation (S) and range of values for the variables controlled in Experiment 3.Note: AoA = Age of acquisition, Name Agree't = Name agreement, No.of Syl's = Number of syllables.

3.3.1.3 *Procedure*

The stimuli were presented as black and white line drawings from Snodgrass and Vanderwart (1980) and Morrison et al. (1997). In the same session the set of 32 pictures was presented twice (once to be named in one language; once to be named in the other language). Participants were divided into two groups, with half of the participants naming the pictures in English first and in Spanish second and half naming the pictures in Spanish first and in English second. Twenty pictures were presented for practice naming in English and in Spanish at the beginning of the experiment. The stimuli were presented using a Macintosh Centris 660-AV computer. Subjects sat facing the computer screen, which was about 60 cm in front of them. A fixation dot appeared in the centre of the screen for 1000 ms before each picture was presented. Pictures remained on the screen until the participant made a response. Response timing began at the onset of the stimulus. Verbal responses triggered a voice key linked to a high-sensitivity microphone attached to headphones worn by each participant. There was then an inter-trial interval of 500 ms before the presentation of the next fixation dot. Participants were asked to name the items as quickly and as accurately as possible. Presentation of items and recording of reaction times was done using the SuperLab experiment generator package (Abboud, 1991). The experimenter noted any naming errors, hesitations, misfirings of the voice key etc. There was no pre-exposure to the items before the experiment.

3.3.2 Results

Only naming times for correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Consequently eleven responses (0.78%) that fell outside 3.5 standard deviations were removed. A further 31 responses (2.20%) were removed from the Spanish language condition because of naming errors, hesitations and voice key failures, and 91 responses (6.46%) from the English language condition. Table 3.3 shows the mean naming RT and error percent in each condition.

		Early acquired		Late acquired	
		Named 1st	Named 2nd	Named 1st	Named 2nd
Spanish (L1)					
RT	M	803	1023	894	1030
	S	134	269	115	215
% error		0.48	0.43	0.85	0.64
English (L2)					
RT	M	1054	1109	1229	1123
	S	195	380	292	235
% error		0.85	0.92	2.27	2.41

Table 3.3 Mean RT (M), standard deviation (S) and percent errors (% errors), for early and late acquired items named first or second in L1 and L2 in Experiment 3.

3.3.2.1 *Reaction time analysis*

An analysis of variance was carried out with AoA and language as within-subjects factors and order as between-subjects factor in the analysis by subjects, and with order as a within-item factor and AoA and language as between-item factors in the analysis by items. The main effect of language was significant in both analyses, $F_1(1,20) = 8.10$, $MSE = 804028.93$, $p<0.05$; $F_2(1,60) = 37.55$, $MSE = 1179969.14$, $p<0.001$, with naming responses being faster in Spanish than in English. The main effect of AoA was also significant, $F_1(1,20) = 6.82$, $MSE = 114719.08$, $p<0.05$; $F_2(1,60) = 8.72$, $MSE = 274136.02$, $p<0.01$, with early acquired items being named faster than late acquired items. The main effect of order was significant only in the by-items analysis, $F_1(1,20) = 1.22$, $MSE = 127737.13$, $p>0.1$; $F_2(1,60) = 8.9$, $MSE = 179955.89$, $p<0.01$, where items named for the first time (996 ms) were faster than for the second time (1071 ms).

The interaction between order and AoA was significant, $F_1(1,20) = 4.89$, $MSE = 82261.28$, $p<0.05$; $F_2(1,60) = 5.98$, $MSE = 121067.89$, $p<0.05$, meaning that the AoA effect was larger overall for pictures named first than for pictures named second. A series of t-test analyses were carried out for the Spanish and English and for the first and second naming. They revealed significant AoA effects for English, $t(10) = -2.33$, $p<0.05$, and for Spanish, $t(10) = -3.25$, $p<0.01$, but only for the picture naming tasks done first. A second series of t-tests showed that the interaction between order and AoA was mainly caused by early acquired words slowing down dramatically during the second time of task completion. Overall the RT difference between early acquired words named first or second was significant, $t(21) = -2.00$, p=0.05, whereas the difference between naming late acquired words first or second was not significant, $t(21) = -0.22$, p>0.1. The interaction is shown in Figure 3.1. An interaction between order and language was found only in the analysis by items, $F_2(1,60) = 16.53$, $MSE = 334286.94$, p<0.001. According to this interaction, the main effect of order (faster RT for the first naming than for the second naming) was bigger in L1 (Spanish) than in L2 (English). The form of this interaction is shown in Figure 3.2.

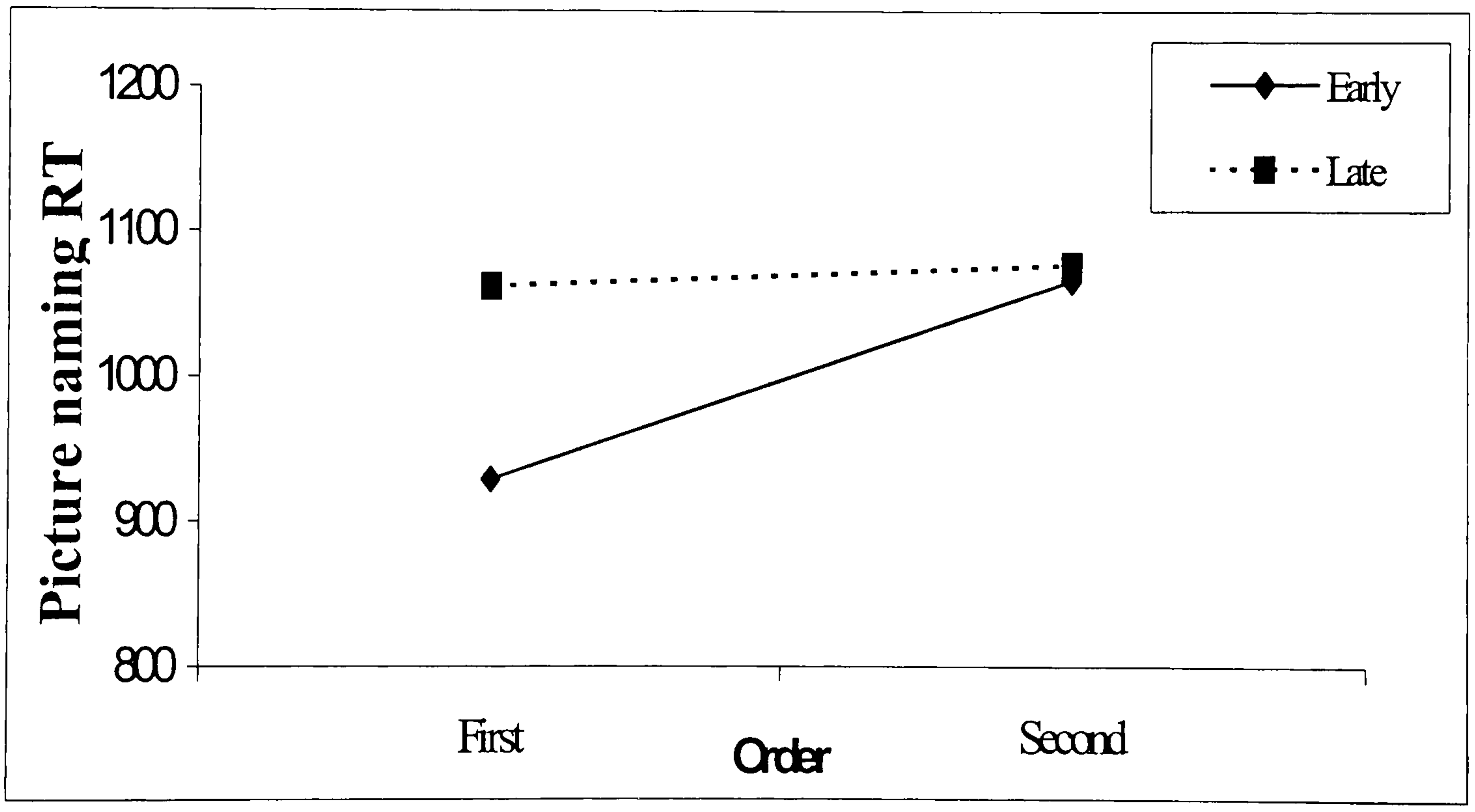


Figure 3.1 The interaction between order and AoA in Experiment 3.

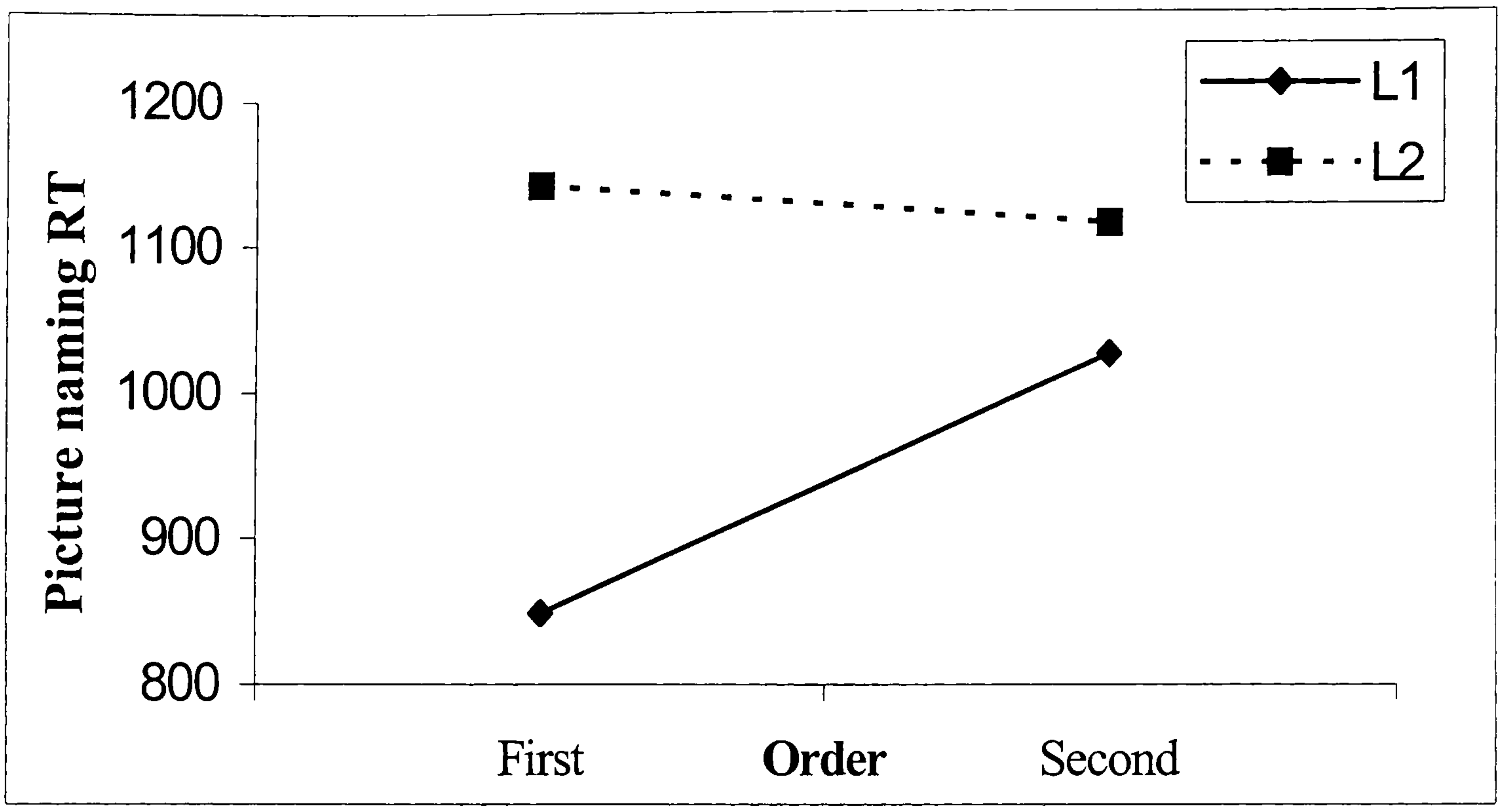


Figure 3.2 The interaction between order and language in Experiment 3. Note: L1 = Spanish, L2 = English.

3.3.2.2 *Error analysis*

The low number of errors precluded the use of analysis of variance. Analysis of the mispronunciation rates using the Wilcoxon matched-pairs signed-ranks test revealed a significantly higher rate of errors to late than to early acquired words in English as a second language, $Z = -2.86$, $p<0.01$. The difference in error rates for early and late acquired words in the native Spanish language condition was also significant, $Z = -1.93$, $p<0.05$

3.3.3 Discussion

Considering for the moment only the task done first in Experiment 3, AoA effects were found for the production of Spanish object names that were learned as part of the participants' acquisition of their native language vocabulary. This replicates previous reports of native language AoA effects in picture naming for Spanish (Cuetos et al., 1999) as well as for French (Kremin et al., 2000) and English (e.g., Barry et al., 1997; 2001; Carroll & White, 1973b; Ellis & Morrison, 1998). An effect of AoA was also found when participants named the same pictures in English. None of the participants had known any English before the age of 8 years, and the AoA effect was based on a distinction between English words learned within the first two years tuition in English and words learned in or after the third year of studying English. This is the first demonstration of AoA effects in a second language. It is not really possible to compare ages of acquisition in first and second languages directly, but we note that there was no indication of the effect of AoA on naming RTs being weaker for the second than for the first language indeed it tended to be larger. This AoA effect found in English as a second and late learned language suggest that origins of the effect lie in the order of word learning rather than the age of the speaker when the words were learned.

The results of the second part of Experiment 3, however, were unexpected. Results showed that initial naming in L2 slowed down subsequent naming times in L1 (1027ms) when it was compared with naming pictures in L1 for the first time (849ms). However, L2 was not affected by previous naming in L1 (1142ms the first time versus 1116ms the second time).

Most bilingual models accept the idea of a parallel activation of both languages when bilinguals comprehend and produce words even when the task or situation demands the activation of only one of the two languages (Colomé, 2001; Dijkstra, De Bruijn, Schriefers, & Ten Brinke, 2000; Dijkstra & Van Heuven, 1998; Roelofs, 1992). The source of disagreement between researchers resides on whether or not the activated words in both languages compete for lexical selection (Costa, Miozzo, & Caramazza, 1999). That is, whether or not bilingual lexical selection is language specific. The results of Experiment 3 showed that naming pictures in L2 slowed down subsequent naming in L1 but not vice-versa. These results did not support the notion of a language-specific lexical access (Costa et al., 1999). In this view, bilinguals only consider the target language for selection. The results of Experiment 3 could be better explained in terms of the non language-specific view. The two languages of a bilingual get activated simultaneously and the two lexicons are considered for selection. Naming pictures in L2 first slowed down subsequent naming in L1 because of the necessary inhibition to be imposed on L1 in order to select the correct name in L2. This inhibition had to be surpassed when L1 was required straight after creating a cost of time. L2 was not as influenced by L1 because the non-dominant language does not need to be as strongly inhibited when using L1. This interpretation is supported by Meuter and Allport's (1999) findings in language switching and by the inhibitory control model, IC, proposed by Green (1998). The IC model suggests an inhibitory control mechanism whose main purpose is to allow bilinguals speaking in one language without the interference from the other language. This inhibitory mechanism is reactive, therefore the more active a non-target lemma is the more inhibited it will be and activating inhibited lemmas is a function of the prior amount of suppression.

The interaction found between AoA and order indicated an AoA effect larger when the task was done first than when the task was done second. The reduction in the AoA effect was caused fundamentally by the slowing down on early acquired object names when participants named these objects the second time. Late acquired objects were produced at similar speed in both orders. Interestingly the picture names that suffer most in second naming were early acquired words in Spanish. It is conceivable to think that if activated lemmas in L1 have to be inhibited because being the dominant language are easily activated, early acquired words could have suffered a higher inhibition than late acquired words. Green's I C model (1998) suggests that the inhibition imposed in the non-target language is reactive; that is, the more active a non-target lemma the more inhibited it will be. Early acquired words in L1 but also in L2 will produce a quick and strong activation and therefore a high inhibition needs to be imposed on them. When these object names have to be retrieved some time after the inhibition has to be overcome, and the word activated for production causing a cost of time. In Experiment 3 the reactivation cost for early acquired words in L1 and L2 might have caused the interaction between AoA and task order.

3.4 Experiment 4 – Lexical decision and AoA

Robust effects of AoA in first languages have also been observed in the visual lexical decision task, where participants must decide as quickly as possible if a string of letters on the screen constitutes a real word or an invented nonword (e.g., Butler & Hains, 1979; Gerhand & Barry, 1999; Morrison & Ellis, 1995, 2000). Experiment 4 applied the same logic as Experiment 3 in an effort to discover whether AoA effects could be detected in English as a second language as well as in Spanish as a first language, not only in a word production task, such as picture naming, but also in a word recognition task, such a lexical decision.

3.4.1 Method

3.4.1.1 *Participants*

The participants were 22 native speakers of Spanish (11 females and 11 males) with a mean age of 26 years (range 20-33 years) whose childhood had been spent in Spain. The mean age at which they first began to learn English was 10 years (range 7-14 years). At the time of testing, all the participants were studying at the University of York, England. They had been resident in England, using English on a daily basis, for a mean time of 2 years and 4 months (range 4 months to 8 years).

3.4.1.2 *Materials*

The stimulus words were 38 Spanish object names taken from Cuetos et al. (1999) and 38 English object names taken from Morrison et al. (1997). An effort was made to avoid the use of cognates and unlike Experiment 3, to avoid competition effects, the Spanish and English words were not translation equivalents (i.e., they were the names of different objects). Each set of 38 words was divided into two sets of 19 early and 19 late acquired words. For the Spanish words this was done using the Cuetos et al. (1999) AoA ratings for Spanish as a first language. The English words were divided into early and late acquired in English as a second language on the basis of the ratings obtained for Experiment 3. The word sets were matched on word frequency in English using the Celex database (Baayen et al., 1993) and the Hofland and Johansson (1988) frequency count, and on word frequency in Spanish from Alameda and Cuetos (1995). Early and late sets were matched within languages on number of letters and phonemes. Mean, standard deviation and range of values for each variable are shown in Table 3.4. The items and their characteristics are shown in Appendix 4.

Stimulus set		AoA	Frequency	No of Phonemes	No of Letters
Early	M	3.80	1.26	5.58	5.74
acquired	S	0.33	0.39	1.30	1.33
Spanish items	Range	3.04 – 4.26	0.70 – 1.78	4 - 8	4 - 8
Late	M	4.69	1.27	5.47	6.00
acquired	S	0.38	0.46	1.26	1.20
Spanish items	Range	4.27 – 5.34	0.78 – 2.28	3 - 8	4 - 9
Early	M	18.82	1.14	4.05	4.95
acquired	S	4.11	0.42	1.51	1.61
English items	Range	17.40 – 25.20	0.11 – 1.73	2 - 7	3 - 9
Late	M	37.70	1.22	4.11	4.89
acquired	S	8.68	0.18	1.33	1.41
English items	Range	29.65 – 60.63	1.00 – 1.53	2 - 7	3 - 8

Table 3.4 Mean (M), standard deviation (S) and range of values for the variables controlled in Experiment 4. Note AoA = Age of acquisition, No of Phonemes = Number of phonemes, No of Letters = Number of letters.

Nonwords for use in the Spanish and English parts of the experiment were created from real words in those languages by changing one or two letters in such way that they remained orthographically legal and pronounceable. The number of nonwords used was the same as the number of words for each language condition; 38 nonwords for the Spanish lexical decision and 38 nonwords for the English lexical decision. Examples of Spanish nonwords are *jomo* and *rela*. Examples of English nonwords are *therry* and *brean*.

3.4.1.3 *Procedure*

The experiment was carried out using a Macintosh centris 660-AV computer. Participants sat facing the computer screen, which was approximately 60 cm in front of them. The stimuli were presented on the computer screen in lowercase 48 point New York font. Each trial began with a fixation dot in the centre of the screen for 1000 ms, followed by the word or nonword which remained on the screen until a response was made. Participants pressed the P key on a standard Qwerty keyboard if the item was a word and the Q key if it was a nonword.

The experiment consisted of two parts, an English language part in which English words were distinguished from nonwords and a Spanish language part in which Spanish words were distinguished from nonwords. Participants were divided into two groups. One group of 11 participants received the English version and then a Spanish version, while the order of the two languages was reversed for the other group. Each part of the experiment began with 10 practice items in the appropriate language (5 words and 5 nonwords). Presentation of items and recording of reaction times was done using the SuperLab experiment generator package (Abboud, 1991).

3.4.2 Results

Only correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Eight responses (0.48%) to Spanish words and 19 responses (1.14%) to English words fell outside 3.5 standard deviations for words in that language and were removed from the analysis. Six additional responses (0.36%) to Spanish words and 16 responses (0.96%) to English words were errors that involved pressing the wrong response key. Table 3.5 shows the mean RT, standard deviations and error rates collapsed across the two task orders.

		Early acquired		Late acquired	
		1st Decision	2nd Decision	1st Decision	2nd Decision
Spanish (L1)					
RT	M	685	615	722	668
	S	126	99	134	81
% error		0.48	0.48	0.23	0.23
English (L2)					
RT	M	701	673	789	764
	S	57	125	111	194
% error		0.23	0.48	1.67	1.43

Table 3.5 Mean RT (M), standard deviation (S) and percent errors (% errors) for first or second decision times to early and late acquired items in L1 and L2 in Experiment 4.

3.4.2.1 *Reaction time analysis*

An analysis of variance was carried out on the reaction times to real words, with task order, AoA and language as factors. The main effect of language was significant only in the analysis by items, $F_1(1, 38) = 2.13$, $MSE = 51546.97$, $p > 0.1$; $F_2(1,76) = 10.21$, $MSE = 91199.29$, $p < 0.01$, with lexical decision responses tending to be faster to Spanish words than to English words. The main effect of AoA of acquisition was significant in both by-subjects and by-items analyses, $F_1(1, 38) = 36.05$, $MSE = 78229.79$, $p < 0.001$; $F_2(1,76) = 14.04$, $MSE = 125444.95$, $p < 0.001$, with early acquired items being correctly classified as real words faster than late acquired items. The effect of task order was significant only in the analysis by items, $F_1(1,38) = 2.09$, $MSE = 50634.25$, $p > 0.1$; $F_2(1,76) = 23.82$, $MSE = 108936.23$, $p < 0.001$, with words being classified faster in the second part of the experiment than in the first, suggesting a general practice effect. No significant interactions were found, though there was a numerically larger effect of AoA in English (69 ms) than in Spanish (43 ms).

The mean RT for correctly rejecting nonwords in the Spanish and English language conditions were 923 ms and 1059 ms respectively. The difference in reaction times was not significant, $t(21) = -1.68$, $p = 0.11$.

3.4.2.2 *Error analysis*

The low number of errors precluded the use of analysis of variance. Analysis of the error rates using the Wilcoxon matched-pairs signed-ranks test revealed a significantly higher rate of errors to early than to late acquired words in English as a second language, $Z = -2.06$, $p < 0.05$, but no significant difference was found for the native Spanish language condition, $Z = -0.74$, $p = 0.46$, where few errors were made.

Nonwords were correctly rejected with an accuracy of the 98% for the Spanish nonwords and 96% for the English nonwords. This difference in error rates was not significant, $t(21) = -1.27$, $p = 0.22$

3.4.3 Discussion

The AoA effect in Spanish in Experiment 4 is consistent with the Spanish AoA effect found in Experiment 2 and with similar results found with native speakers of English (Butler & Hains, 1979; Gerhand & Barry, 1999; Morrison & Ellis, 1995, 2000). Importantly an effect of AoA was also found in the English language version of the experiment. Bilinguals who had acquired English after the age of 10 distinguished English early acquired words from nonwords faster than English late acquired words. This result does not support the notion of a close link between AoA effects and critical period.

3.5 General Discussion

Taken together, the results of Experiments 3 and 4 establish the presence of an AoA effect in the production and recognition of words acquired in a second language after the stage of early childhood. This AoA effect found in L2 suggests that the effect is clearly not due to the age of vocabulary acquisition. As a consequence, the effect of AoA does not seem constraint to a critical period for word learning. Supporting these results are the studies that looking at maturational constraints for language acquisition have not found age limitations for lexical acquisition. Davis and Kelly (1997) argued that the lexicon is an aspect of language less vulnerable to critical period effects. Similarly, Markson and Bloom (1997) found that children and adults are as good at learning and remembering novel names.

Ellis and Lambon Ralph (2000) successfully implemented AoA effects in a connectionist network. They suggested that the origin of the effect in the model was linked to a loss of network plasticity. The network became more rigid with increased training causing a disadvantage for late acquired patterns. The applicability to human data of this loss of network plasticity is not strongly supported by the results of Experiment 3 and 4. These results support the idea advanced by Yamazaki et al. (1997) that it is the order and not the age at which words are acquired the responsible for the AoA effect.

A competition effect across languages was found in Experiment 3. The use of the same stimuli for the picture naming task in Spanish and in English might have caused a significant interference across languages.

However, in Experiment 4 the words contained in the Spanish lexical decision task were not translation equivalents of the words used in the English lexical decision task, reducing the likelihood of competition effects.

However, the early stimuli sets in Experiments 3 and 4 were acquired early both in Spanish as a first language and in English as a second language, while the late acquired sets were acquired late both in Spanish as a first language and English as a second language. One possible account of the results of Experiments 3 and 4 would be that AoA effects in both first and second languages depend on the age at which the meanings of the words are acquired (in the first language). If, as most theorists assume (De Bot, 1992; Costa et al., 1999; Hell & De Groot, 1998; Kroll & Stewart, 1994), first and second languages share common semantic representations, then second language vocabulary could inherit the AoA characteristics of the corresponding words in the first language. Chapter Four explores in some detail the nature of the second language AoA effect and addresses this issue.

CHAPTER FOUR

IS SECOND LANGUAGE AoA INDEPENDENT FROM FIRST LANGUAGE AoA?

4.1 Introduction

The results of Chapter Three showed a significant effect of age of acquisition (AoA) in naming pictures and recognising words in the first (L1) and the second (L2) language of bilinguals. This suggested that the AoA influence is not due to maturational differences in the time at which words are acquired but that it is the result of the order at which vocabulary is learned.

However, the AoA values of the stimuli sets in Experiments 3 and 4 were the same across languages. As was discussed in section 3.5 previously, second language vocabulary could inherit the AoA properties of the translation equivalents in the first language through the shared semantic representations. For example, the word *caja* is learned early in the acquisition of Spanish as a native language, and its translation equivalent, *box,* is learned early in the acquisition of English as a second language. The word *cometa* is learned somewhat later in the acquisition of Spanish as a native language, and its translation equivalent, *kite*, is likewise learned relatively late in the acquisition of English as a second language. The effect of AoA in L2 revealed in the faster naming and lexical decision responses to the English word *box* than to *kite* by native speakers of Spanish may simply reflect the differences in AoA of *caja* and *cometa* in L1, Spanish.

A dependence of second language AoA effects on the age at which words are learned in L1 could arise if the source of AoA effects lies in the semantic representations (Brysbaert, Van Wijnendaele et al., 2000). If the semantic representations of early acquired words were in some way easier to activate than the semantic representations of late acquired words, then any task that involved semantic representations would be expected to show AoA effects. Most theoretical accounts of object naming propose that the conversion of a perceptual description of an object or picture to a phonological code for speech output is mediated by an intervening stage at which semantic knowledge of the depicted object is activated (e.g., Humphreys, Price, & Riddoch, 1999; Levelt, Roelofs, & Meyer, 1999). Hence, AoA effects would be expected in first language object naming, which they are. If it was the case that acquiring the name of an object in L2 involved associating a new word-from with a pre-existing semantic representation created when the object was first encountered and talked about, and if AoA was reflected in those semantic representations, then the naming of an object in a second language would inherit the influence of AoA generated during childhood and the acquisition of L1 vocabulary. That could account for the second language AoA effect seen in Chapter Three, Experiment 3.

Similarly, at least some theoretical accounts of lexical decision propose that one of the ways that participants distinguish words from nonwords is on the basis that familiar words cause much stronger semantic activation than nonwords do (e.g., Plaut, 1997). Support for this view may be sought in demonstrations that lexical decision is faster for words with concrete meanings than for words with abstract meanings

(Hell & de Groot, 1998) and faster for words with several meanings than for words with a single meaning (Hino & Lupker, 1996). Although these studies did not take AoA into consideration, Morrison and Ellis (2000) showed that imageability predicted lexical decision times along with AoA and frequency. These findings implicate semantic representations in lexical decision. Once again, if acquiring a word in a second language involved forming an association between the new word-form and an old semantic representation which was consulted in the course of making a lexical decision response, then lexical decision to second language words would inherit the childhood AoA effect residing in the semantic system. That could account for the AoA effect in L2 seen in Chapter Three, Experiment 4.

This possibility – that AoA is an inherent characteristic of semantic representations – would predict that word recognition and production in the second language would show AoA effects that reflect the order of acquisition of the corresponding meanings or word-forms in the first language. The results of Experiments 3 and 4 do not speak to this possibility because the items selected were early or late acquired in both L1 (Spanish) and in L2 (English).

The order of acquisition of second language vocabulary echoes to an extent the order of acquisition of native language vocabulary, so that words learned early in the native language tend also to be learned early in the second language. But the two orders of acquisition do not mirror one another exactly. Second language learners tend to be introduced early on to vocabulary that has to do with surviving in a foreign country – vocabulary to do with renting accommodation, buying food and other items in shops, handling money, and so on. Young children are protected from such concerns, so tend to acquire the corresponding native vocabulary later. In contrast, children acquire early on a vocabulary that has to do with the world of stories and the imagination – words to do with giants and castles, fairies and dragons. Second language learners have less use for such words which tend to be acquired relatively late in a non-native language.

Therefore, there are some words that are deemed useful for adults to learn early in L2 whose translation equivalents are not acquired until late in L1 and, conversely, there are some words acquired early in L1 that are considered low priorities for adult second language acquisition and so tend to be learned late.

The account of second language AoA effects that I have just outlined would predict that processing speed in the second language would reflect first language AoA, irrespective of the order in which the equivalent words are learned in the second language. This prediction was tested in Experiment 5 which employed the lexical decision task, and asked whether lexical decision RTs in a second language was better predicted by second language AoA or by the AoA of the corresponding words (translation equivalents) in the first language. A regression analysis approach was chosen as a technique that allows the use of a wide range of stimuli, since words referring to abstract and concrete meanings can be used. It also permits the observation of the relative contributions of several predictor variables over latencies. The main variables of interest were AoA in L2 (English) and AoA of the corresponding word in L1 (Spanish). Other predictors were imageability, word frequency in English, number of orthographic neighbours of the English word and word length in letters.

4.2 Experiment 5 – A multiple regression account of the AoA effect in English as a second language.

4.2.1 Method

4.2.1.1 *Participants*

Twenty-two native Spanish speakers (9 males and 13 females) with a mean age of 26 (range 18-33 years) who had learned English as a second language took part in the experiment. As in the previous experiments, all the participants had spent their childhoods in Spain. The mean age at which they started learning English was 14 years (range 8-22 years) and they had been learning English for a mean time of 11 years (range 5-20 years). They were all students at the University of York, England and had been resident in England for a mean time of 2 years (range 6 months – 5 years).

4.2.1.2 *Materials*

The experimental stimuli were 199 words and an equal number of non-words. One hundred and two of the words were taken from the set previously rated on AoA in Spanish as a first language (Cuetos et al., 1999) and English as a second language (Experiment 3). The remaining 97 items came from a set of 160 words that were mostly selected on the basis that their ages of acquisition might be rather different in L1 and L2; for example, words related to children's games or stories (e.g. cradle, marble, fairy) which might be learned early in L1 but late in L2, or words related to adult daily life (e.g. expensive, rent, welcome) which might be learned late in L1 but early in L2. New ratings of AoA for L1 (Spanish) were collected from 20 native speakers of Spanish using the same scale as employed by Cuetos et al. (1999). The new set included 40 words which also occurred in the previous ratings studies. The correlation between the new and old ratings for those 40 items was r = 0.89.

Age of acquisition in English as a second language. New ratings were also obtained for the 160 new items for AoA in L2, English. Twenty Spanish – English dominant bilinguals, resident in England, estimated the point at which they had acquired 160 English words in their process of learning English. For this purpose, the same scale as described in Chapter Three, Experiment 3 was used (ranging from 1= learnt in the first year of English learning to 7+ = learnt in the seventh year of English learning or later, with an additional box labelled N.A. (Not Acquired) for those words not yet acquired). Forty of the words had been previously rated for Experiment 3. The correlation between the ratings for those items was r = 0.92. The 97 new items added to the 102 for which ratings already existed were all known by at least 80% of the raters.

Imageability. Twenty English native speakers were asked to rate 138 words as to how easy or difficult these words conjure a mental image, from 1 = hard to form an image to 7 = very easy to form an image. Imageability ratings for the 61 additional words were taken from Morrison et al. (1997).

Word frequency. The word frequency measure used was the combined written and spoken count from the CELEX database, which is based on a large corpus of contemporary British English (Baayen et al., 1993).

Number of orthographic neighbours (N). This was defined as the number of English words that differ from the target word by a single letter.

Word length. The number of letters in the English word was taken as the measure of length.

The full set of items with their values on the predictor variables and their RT is shown in Appendix 5. One hundred and ninety-nine legal, pronounceable nonwords in English were created by changing single letters in a new set of English words. The English nonwords were not words in Spanish.

4.2.1.3 *Procedure*

The stimuli were presented in the centre of an Apple Mac Centris 660 – AV computer screen in black 48 lowercase print using New York font. The screen was approximately 60 cm away from the participant. The order of presentation was randomised (words and nonwords) separately for each participant. A 1-second fixation dot was followed immediately by the stimulus word or nonword which remained on the screen until the participant made a response, whereupon the fixation dot reappeared. Participants were instructed to decide as quickly and as accurately as possible if the stimulus item was a word or a nonword. They pressed the P key for words and the Q key for nonwords. Presentation of the items and recording of the reaction times was controlled by the SuperLab experiment generator package. Twenty practice items (10 words and 10 nonwords) were presented at the start of the experiment.

4.2.2 Results

Only correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Fifty-three responses (1.21%) to English words fell outside 3.5 standard deviations and were removed from the analysis. An additional 209 responses (4.77%) to words were errors that involved pressing the wrong response key. Mean accuracy of nonword rejection was 93%. Overall, the mean RT for correct responses to words was 723 ms while the mean RT for correct rejections of nonwords was 911 ms.

Word frequency and number of orthographic neighbours were subjected to a log (1+x) transform while the other predictors were square root transformed to reduce skew. Table 4.1 shows the intercorrelations of the predictor variables and their correlation with mean lexical decision

RT. AoA in the second language showed the highest correlation with RT, followed by word frequency, word length and number of orthographic neighbours. Imageability and AoA of the corresponding words in Spanish as a first language did not correlate significantly with lexical decision RT in English.

	1	2	3	4	5	6	7
1 RT	1.00	.066	.545*	.102	-.464*	-.203*	.340*
2 Spanish AoA		1.00	.277*	-.466*	.054	-.261*	.228*
3 English AoA			1.00	-.002	-.495*	-.046	.115
4 Imageability				1.00	-.398*	.228*	-.096
5 Word frequency					1.00	.045	-.142
6 N						1.00	-.778*
7 No. letters							1.00

*p < .01

Table 4.1 Correlation matrix among all the independent variables and English (L2) lexical decision RT in Experiment 5. Note: N = number of orthographic neighbours, AoA = Age of acquisition, No. letters = Number of letters.

4.2.2.1 *Reaction time analysis*

The six predictor variables were entered into a simultaneous multiple regression analysis with each item's mean lexical decision RT as the dependent variable. The results are shown in Table 4.2. Taken together, the independent variables were able to predict English lexical decision RT to a significant degree, $F(6,192) = 23.60$, $MSE = 127008.17$,

$p<0.001$, accounting for 43% of the variance in RT. The factors exerting significant independent effects on lexical decision speed were AoA in English as a second language, English word frequency and word length. The AoA of the equivalent words in Spanish as a first language did not make an independent contribution to predict RT, neither did the imageability of the words or their number of orthographic neighbours (N).

	B	Standard Error	Beta coefficient	t value	Significance
Spanish AOA (L1)	-35.61	21.61	-.108	-1.65	.101
English AOA (L2)	35.56	5.47	.442	6.50	.001
Imageability	-1.97	18.26	-.008	-0.11	.914
Word frequency	-29.95	10.86	-.199	-2.76	.006
N	11.25	19.35	.052	0.58	.562
No. letters	87.34	23.91	.325	3.65	.001

Table 4.2 Results of the simultaneous multiple regression analysis of English lexical decision RT in Experiment 5. Note: N = Number of orthographic neighbours, AoA = Age of acquisition, No. letters = Number of letters.

To assess the effect that AoA in L2 exerts in decision latencies after the effects of word frequency and word length have been removed, a hierarchical regression analysis was carried out. To do this the six predictors were entered into the regression analysis in two different blocks. The first block with word frequency, word length, Spanish AoA

(L1), imageability and number of neighbours, and the second block with the same variables in addition to English AoA (L2). The difference between the proportion of variance explained by the variables entered in the first block and those entered in the second block was significant, $F(5,192) = 42.27$, $p<0.001$. The increase in proportion of variance ($R^2 = 0.127$) when English AoA (L2) was entered into the analysis indicates that second language AoA accounts for 13% of unique variance. The same technique was used to assess the strength of the effects of word frequency and word length. Word frequency explained 2% of unique variance and the increase in proportion of variance accounted for by the model when word frequency was added to the analysis was significant, $F(5,192) = 7.60$, $p<0.05$. Word length accounted for 4% of unique variance and the increase of variance accounted for when number of letters was included in the analysis was also significant, $F(5,192) = 13.34$, $p<0.001$.

4.2.2.2 *Error analysis*

A simultaneous multiple regression analysis was calculated with percentage of errors (log transformation) as the dependent variable. AoA of L1 and L2, number of letters, number of neighbours, word frequency and imageability significantly predict percentage of errors, $F(6,192) = 14.81$, $MSE = 8.934$, $p<0.001$, accounting for 32% of the variance. The analysis of errors and RT revealed similar results. AoA in L2 ($p<0.001$) and word length ($p<0.05$) emerged as significant predictors of accuracy with word frequency approaching significance ($p = 0.07$).

4.2.3 Discussion

Inspection of Table 4.1 shows that for the 199 words used in Experiment 5 the correlation between AoA in L1 (Spanish) and AoA in L2 (English) was $r = 0.277$. But, although the two AoA measures were themselves intercorrelated, only AoA in L2 correlated significantly ($r = 0.545$) with lexical decision RT for English words from participants who had acquired English as a second language. The correlation between lexical decision RT in English and the AoA of the corresponding Spanish words was just $r = 0.066$.

In the regression analysis, AoA in L2 (English) made a significant contribution to the prediction of lexical decision speed and accuracy in English but AoA of the corresponding words in Spanish did not. The other variable that significantly predicted RT was the frequency of words in English: faster RT were associated with words learned early in L2 and encountered with higher frequencies. This observation of independent contributions of frequency and AoA to lexical decision speed is in line with previous findings in the monolingual domain (e.g., Gerhand & Barry, 1999; Morrison & Ellis, 1995, 2000). Finally, word length also predicted decision latencies and accuracy. Word length effects in lexical decision tasks have also been observed in studies where the word length measure covered a wide range of letters as in Experiment 5 (Butler & Hains, 1979; Gilhooly & Logie, 1981b).

Table 4.1 shows that the age at which words are acquired in Spanish (L1) correlates significantly ($r = 0.466$) with imageability, meaning that words with more concrete, imageable meanings are learned earlier in L1 than words with more abstract meanings. High correlations between AoA in native languages and imageability have been reported in a number of studies (e.g., Morrison et al., 1997; Rubin, 1980). This high correlation between AoA and imageability was considered by Brysbaert, Van Wijnendaele et al. (2000) as an indication of the semantic nature of the AoA effect. It is notable, though, that imageability has a correlation with AoA in L2 that is virtually zero (r = -0.002). This might be a consequence of the different needs and language experiences between an adult second language learner and a child. Second language learners must learn the vocabulary of the adult world if they are to get by in another country: abstract words to do with finding accommodation, organising money and so on are aspects of adult life from which young children are mercifully protected.

4.3 Experiment 6 – A factorial account of the AoA effect in the first and the second language

4.3.1 Introduction

Experiment 5 indicated that the age at which words are acquired in the second language is a more important predictor of word recognition speed in the second language than is the AoA of the corresponding words and their meanings in the first language. This suggestion was tested further in Experiment 6. Using the ratings obtained for Experiment 5 it was possible to select two sets of items. The first were words whose Spanish equivalents are learned early in Spanish as a first language but whose English forms are learned relatively late in the acquisition of English as a second language. Examples are *hada/fairy* and *muñeca/doll.* The second set were words with the opposite characteristics, words whose Spanish equivalents are learned relatively late in Spanish as a first language but whose English forms are learned early in the acquisition of English as a second language. Examples are *barato/cheap* and *viaje/travel*.

As before, the participants were native speakers of Spanish who were born and raised in Spain, who learned English as a second language, and who were resident in England (mostly as visiting students) at the time of testing. Half the participants performed lexical decision in Spanish to the Spanish versions of the words (*hada, muñeca, barato, viaje,* etc.) while the other participants performed lexical decision in English to the English versions of the words (*fairy, doll, cheap, travel*, etc.). If the indications of Experiment 5 are correct, then the group presented with Spanish words to recognise should be faster to the early Spanish / late English items than to the late Spanish / early English items while the group presented with English words to recognise should be faster to the late Spanish / early English items than to the early Spanish / late English items.

4.3.2 Method

4.3.2.1 *Participants*

Forty-four native Spanish speakers (21 males and 23 females) with a mean age of 26 (range 19-46 years) who had learned English as a second language took part in the experiment. All the participants had spent their childhood in Spain. The mean age at which they started learning English was 12 years (range 8-26 years) and they had been learning English for a mean time of 10 years (range 2-24 years). They were mostly students at the University of York, England, and had been resident in England for a mean time of 1 year (range 2 months - 5 years).

4.3.2.2 *Materials*

Stimuli consisted of one set of 18 items whose AoA ratings indicated that they were learned relatively early in L1 (Spanish) and relatively late in L2 (English) and a second set of 18 items whose AoA ratings indicated that they were learned relatively late in L1 (Spanish) a and relatively early in L2 (English). The items had different forms in the two languages (i.e. they were not cognates). The sets were matched on English word frequency (Celex: Baayen et al., 1993) and on Spanish word frequency (Alameda & Cuetos, 1995); also on imageability and letter length in the two languages. Details of the matching are shown in Table 4.3. The items and their characteristics are shown in Appendix 6. Thirty-six nonwords with English orthographic characteristics and 36 nonwords with Spanish orthographic characteristics were selected from the sets used in Experiment 5.

	Early Spanish (L1) / Late English (L2)			Late Spanish (L1) / Early English (L2)		
	M	S	Range	M	S	Range
AoA L2	41.87	9.84	28.42 – 64.67	22.69	4.39	13.20 – 27.79
AoA L1	3.55	0.48	2.80 – 4.20	5.22	1.06	4.30 – 7.85
L2 Fr. (Celex)	1.15	0.32	0.70 – 2.06	1.16	0.54	0 .00– 1.85
L2 Fr. (K + F)	0.98	0.50	0.00 – 2.11	1.18	0.60	0.00 – 1.95
L1 Fr. (A +C)	1.34	0.40	0.78 – 2.23	1.24	0.57	0 .00– 2.17
Imageability L2	5.59	1.28	2.85 – 6.85	5.47	1.28	2.80 – 6.90
Imageability L1	6.14	0.87	4.65 – 6.96	5.94	1.25	3.65 – 6.96
No. Letters L2	5.72	1.56	4 – 10	5.78	1.86	3 – 9
No. Letters L1	5.94	1.63	3 - 10	5.94	1.83	3 - 9

Table 4.3 Mean (M), standard deviation (S) and range of values for the variables controlled in Experiment 6. Note: Fr (Celex) = Celex frequency count, Fr (K + F) = Kucera and Francis (1967) frequency count, Fr (A + C) = Alameda and Cuetos (1995) frequency count, AoA = Age of acquisition, No. Letters = Number of letters.

4.3.2.3 *Procedure*

The conditions of presentation and mode of response were the same as in Experiment 5. Participants were split in two halves: 22 completed the task in L1 (Spanish) and 22 completed the task in L2 (English). Twenty practice trials were given as practice (10 words and 10 nonwords) at the start of the session.

4.3.3 Results

Only correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Nine responses (1.14%) to Spanish words and 12 responses (1.51%) to English words fell outside 3.5 standard deviations for words in that language and were removed from the analysis. An additional 26 responses (3.28%) to Spanish words and 37 responses (4.67%) to English words were errors that involved pressing the wrong response key. Table 4.4 shows the mean RT, standard deviations and error rates in the two conditions (L1 and L2).

			Early Spanish / Late English	Late Spanish / Early English
Spanish (L1)				
	RT	M	648	668
		S	52	45
	% error		2.52	4.04
English (L2)				
	RT	M	890	768
		S	177	129
	% error		8.84	1.26

Table 4.4 Mean (M), standard deviation (S) and percentage error (% error) in Experiment 6 (lexical decision)

4.3.3.1 ***Reaction time analysis***

By-subjects and by-items analyses of variance were carried out, with language of presentation and stimuli set (early Spanish / late English vs late Spanish / early English) as factors. The main effect of language was significant, $F_1(1,44) = 16.57$, $MSE = 633254.25$, $p<0.001$; $F_2(1,36) = 47.61$, $MSE = 530903.29$, $p<0.001$, with lexical decision responses being faster overall in Spanish (658 ms) than in English (828 ms). The main effect of stimulus set was also significant, $F_1(1,44) = 21.99$, $MSE = 53750.68$, $p<0.001$; $F_2(1,36) = 4.99$, $MSE = 47525.47$, $p<0.05$, with overall RT being faster to the late Spanish / early English set (718 ms) than to the early Spanish / late English set (767 ms).

Importantly, the interaction between language and stimulus set was significant, $F_1(1,44) = 43.99$, $MSE = 107511.09$, $p< .001$; $F_2(1,36) = 9.96$, $MSE = 94843.19$, $p< .01$. Separate analyses of RT in Spanish and English showed that for the group responding to words presented in Spanish, RTs were faster to early Spanish / late English items than to late Spanish / early English items, $t(21) = -2.21$, $p = 0.03$, while for the group responding to words presented in English, RTs were faster to late Spanish / early English items than to early Spanish / late English items, $t(21) = -6.37$, $p<0.001$. In other words, AoA effects in the two languages reflected the age (or order) of acquisition of the different word-forms in those two languages.

The mean RT for correctly rejecting nonwords in the Spanish and English language conditions were 770 ms and 1129 ms respectively. The difference in reaction time was significant, $t(21) = -3.80$, $p<0.001$.

4.3.3.2 *Error analysis*

The low number of errors precluded the use of analysis of variance. Analysis of the error rates using the Wilcoxon matched-pairs signed-ranks test showed that the group responding to English words made more errors to early Spanish / late English words than to late Spanish / early English words, $Z = -3.22$, $p<0.05$. Error rates were low to both word sets in the group responding to Spanish words and the difference was not significant, $Z = -1.05$, $p = 0.294$.

Nonwords were correctly rejected with an accuracy of the 94% for the Spanish nonwords and 92% for the English nonwords. This difference in error rates was not significant (Mann-Whitney U test: $Z = -.85$, $p = 0.396$).

4.3.4 Discussion

The results of Experiment 6 support those of Experiment 4 in Chapter Two and Experiment 5 in the present Chapter. AoA effects were found when native Spanish speakers responded to Spanish words. Those effects reflected the order of acquisition of the words in L1 (Spanish), so RTs were faster to early than late acquired L1 words irrespective of the fact that the L2 versions of the early L1 words are late acquired in L2 and the L2 versions of the late L1 words are early acquired in L2. Conversely, AoA effects were found when native Spanish speakers responded to L2 words that reflected the order of acquisition of the words in English as a second language. Thus, RTs were faster to early than late acquired L2 words, irrespective of the fact that the L1 versions of the early L2 words are late acquired in L1 while the L1 versions of the late L2 words are early acquired in L1. Taken together, the results of Experiments 5 and 6 confirm the presence of AoA effects for second language vocabularies and show that those effects reflect the order in which the second language words are acquired rather than the order in which the equivalent first language words are acquired. The fact that first language AoA did not affect lexical decision latencies in Experiments 5 or 6 suggests that the origin of the AoA effect is lexical (Brown & Watson, 1987; Gerhand & Barry, 2000; Morrison & Ellis, 1995), or lies in the mappings between semantics and lexical representations (Ellis & Lambon Ralph, 2000), but not in the semantic system itself (Brysbaert, Van Wijnendaele et al., 2000).

4.4 General Discussion

The results presented in Chapter Three and Four are relatively clear, and are relatively clear in their implications. In Chapter Three, native speakers of Spanish who started learning English at an average of 11 years of age named pictures and recognised words in either Spanish or English. The words used were either early acquired in both languages or late acquired in both languages. Objects were named and word were recognised faster in the participants' native language of Spanish than in their second language of English, and naming and decision latencies were faster to early than late items in both languages.

Experiments in Chapter Four employed different methodologies to address the question of whether AoA effects in a second language reflect the order of acquisition of words in the second language or the order of acquisition of the equivalent words (and their meanings) in the first language. In Experiment 5, participants responded to English words whose AoA in English as a second language was known, as was the AoA of the translation equivalents in Spanish. In a regression analysis, lexical decision RTs were found to be affected by the AoA of the words in the second language of English but not by the AoA of the first language Spanish equivalents. That is, the effect of AoA seemed to be tied to the age at which the English word-forms had been learned, not the age at which the verbal-semantic representations had been acquired in the native Spanish language.

The indication in Experiment 5 that second language AoA effects reflect the AoA of those words in the second language was supported in Experiment 6. Participants performed a lexical decision task in either L1 (Spanish) or L2 (English). Half the items were ones whose Spanish forms were early acquired in Spanish as L1 but whose English forms were late acquired in English as L2. The other half had the opposite characteristics: their Spanish forms were late acquired in Spanish as L1 but their English forms were early acquired in English as L2. The group responding in Spanish classified the early Spanish set faster than the late Spanish set, irrespective of the fact that the early Spanish items were late acquired in English while the late Spanish items were early acquired in English. More importantly, perhaps, the group responding in English classified the early English set faster than the late English set, irrespective of the fact that the early English items were late acquired in Spanish as L1 while the late English items were early acquired in Spanish.

The combined results of Chapter Three and Chapter Four rule out some possible explanations of how and why AoA effects emerge. First, AoA effects do not appear to depend on a contrast between words learned in early childhood during a possible 'critical period' for language acquisition and words learned later. If they did, then the participants in the present experiments, who only started learning English in late childhood or later, would have been expected to show AoA effects in their native Spanish but not in English. Yet AoA affected the processing of English words in both object naming (Experiment 3) and lexical decision (Experiments 4, 5 and 6). These findings do not support Ellis and Lambon Ralph's (2000) suggestion of the mechanism underlying the AoA effect. Ellis and Lambon Ralph implied that the AoA effects found in their model were due to a loss of plasticity of the network. However, the results of Experiments 4, 5 and 6 showed that this is not the case in human performance.

Second, AoA effects in L2 do not reflect the order of acquisition of the corresponding word meanings in the first language. Both Experiment 5 and Experiment 6 found that the AoA effect for lexical decision in English as a second language was determined by the AoA of the various English word-forms, not the AoA of the corresponding words in Spanish. From this we conclude that while AoA might affect tasks that require accessing meanings (Brysbaert, Van Wijnendaele et al., 2000), the origins of those effects do not lie within the semantic representations themselves.

The results of the present experiments remain compatible with a number of theoretical positions. One is that AoA is a property of orthographic or phonological representations themselves. If orthographic and phonological representations are separate for two languages (De Bot, 1992; Costa et al., 1999; Hell & de Groot, 1998; Kroll & Stewart, 1994), then the representations of early vocabulary could differ from the representations of later vocabulary in some way that gives rise to faster processing of the early items in both languages. For example, Brown and Watson (1987) proposed that as more and more words are learned (in a first language), lexical representations progress from being relatively holistic to being segmented into syllables and phonemes (or letters). Brown and Watson (1987) suggested that the extra processing time required to assemble a late acquired and therefore highly segmented word might account for the slower processing of those words. If this pattern was repeated for words learned in a second language, then the same processing differences could hold for second as for first language vocabulary.

Assuming the principles of the revised hierarchical model (Kroll & Stewart, 1994) researchers who, like Brown and Watson (1987), locate the age of acquisition effect at the level of the lexical representations (e.g., Gerhand & Barry, 1998) would predict two effects of AoA; one emerging from the first language lexical representations and the other from the second language lexical representations. The results shown here are also compatible with this explanation.

A third alternative is that the origins of AoA effects lie in the mappings between different representations of words (orthographic, phonological and semantic) that are forged during the acquisition of both L1 and L2 (Ellis & Lambon Ralph, 2000; Monaghan & Ellis, 2002a, 2002b). According to Kroll and Stewart's model, in the process of learning a second language connections of different strengths are created linking L2 words with L1 words and L2 words with their meanings. Thus, acquiring a second language vocabulary will involve a whole new process of strengthening and weakening connections between representations to create new associations between semantic, phonological and orthographic representations. As with L1 acquisition, words encountered early in the learning of the second language will seize the opportunity to modify connection strengths in directions favourable to representing them. Words learned later in the second language will attempt to reconfigure the new associations, and will succeed to an extent, but because the early second language vocabulary continues to be experienced, used and therefore reinforced, the organisation of the network will forever favour those items learned early in the process of second language acquisition. Second language vocabulary will therefore show AoA effects like first language vocabulary (Chapter Three), and those effects will be determined by the order of acquisition of words in the second language, rather than the order of acquisition of their first language counterparts (Chapter Four).

CHAPTER FIVE

AoA AND ORTHOGRAPHY

5.1 Introduction

Chapters Two and Three showed first and second language age of acquisition effects in picture naming and lexical decision tasks. Chapter Five sets out to examine the age of acquisition (AoA) effect on the first (L1) and second languages (L2) in a word reading task.

Single word naming has in the past generated a considerable amount of research and still does so currently. Its importance resides, perhaps, in the fact that single word naming is a simple task that allows the examination of the factors involved in word reading and its processes.

AoA effects on word naming tasks were explored and detected soon after AoA effects were reported on picture naming latencies. Gilhooly and Logie (1981a) were the first to find a significant influence of AoA on word reading. They used multiple regression analysis as the statistical tool, as did subsequent studies also showing AoA effects in word reading (Baumeister, 1985; Brown & Watson, 1987; Colombo & Burani, 2002; Gilhooly & Logie, 1981b; Morrison & Ellis, 2000; Nagy et al., 1989; Yamazaki et al., 1997). Multiple regression analysis is a powerful statistical technique. It allows the simultaneous study of several factors over a large number of items. However, it has some limitations. Multiple regression analysis is not recommended in the study of highly correlated variables and interactions that are difficult to trace. For these reasons some researchers have opted for factorial designs where one or more variables can be independently manipulated while other factors are controlled for. Studies based on factorial designs have also reported AoA effects on the time it takes to read early and late acquired words (Barry et al., 2001; Coltheart et al., 1988; Gerhand & Barry, 1998; Monaghan & Ellis, 2002a, 2002b; Morrison & Ellis, 1995).

Despite the fact that RTs are generally faster in word naming than in object naming, factorial design studies have revealed that AoA effects tend to be larger in object than in word naming. Barry et al. (2001) conducted an experiment in which participants completed an object and a word naming task, both tasks involving the same stimulus names. They found an interaction between AoA and type of task with an AoA effect of 92 ms for object naming and 32 ms for word naming. To my knowledge there is no other study that has directly compared AoA effects in object and word naming tasks. However, an examination of the literature data can illustrate the differences. Ellis and Morrison (1998) reported 176 ms difference between the naming times of 25 early and 25 late acquired picture names. Similarly, Bogka et al. (in press) found that Greek participants named object and action pictures with 99 ms difference between early and late acquired names. On the other hand, studies of AoA and word naming have reported much reduced AoA effects. Coltheart et al. (1988) found an AoA effect of 15 ms and the same value is shown for the overall word naming times (exception and consistent words) in Monaghan and Ellis's (2002b) study. Finally, Morrison and Ellis (1995) reported an AoA effect of 32 ms.

Two explanations have been offered to account for the differences in the size of the AoA effect across tasks. Barry et al. (2001) suggested that the effect of AoA, whether it is observed in object or word naming tasks, emerges from the lexical representations. Naming a picture always requires access to the lexical forms from the activated semantic representations. However, naming words may be achieved through this same lexical route but occasionally word naming may be accomplished through the sublexical spelling to sound route. This sublexical route bypasses the lexical representations where the AoA effect resides and as a consequence the size of the effect is reduced in word reading tasks.

An alternative explanation as to why the size of the AoA effect varies across tasks is that offered by Ellis and Lambon Ralph (2000). For Ellis and Lambon Ralph (2000), the AoA effect is not restricted to words. Anything that is learnt in a cumulative, interleaved manner implies an order of acquisition and therefore it will become potential material to show AoA effects. They argued that the effect rises from the nature of the connections (arbitrary/predictable) established in the acquisition of new items. Regarding the acquisition of spoken language, arbitrary links are formed between the concepts and the words that represent them because there is nothing in the concept of 'tree' that helps to infer its name in any spoken language. In this case, the order of acquisition is going to play a fundamental role regarding the speed of future object naming. Late acquired object names join a lexical system already formed, they have fewer resources to establish themselves, and there is nothing in the knowledge of early object names that can assist the learning of new object names. Consequently those words acquired first or early create more effective connections than those words acquired some time later.

Regarding the acquisition of written language, the links between the word form and its pronunciation can be more or less predictable depending on the regularity of grapheme-phoneme correspondences that the language holds. Learning to read new regular words (late acquired) benefits from the knowledge acquired when learning to read old regular words (early acquired) since the same grapheme-phoneme correspondences can be used. This benefit that late acquired regular words receive will reduce the cost of having been learned late. It is this advantage that late acquired words enjoy in word reading but not in object naming that produces smaller AoA effects in word reading than in picture naming.

Exceptions to this 'rule' are irregular words. Irregular words such as 'vase' in English cannot get any benefit from previous learning of other words with similar spelling such as 'base' or 'case'. Their form to sound connections become unpredictable and therefore susceptible to AoA effects. Monaghan and Ellis (2002a, 2000b) explored the AoA effect on the reading times of regular and irregular English words. They found an interaction between consistency (regularity of English words) and AoA. AoA affected regular words to a lesser extent than irregular inconsistent words. This result was supported by an extension of Ellis and Lambon Ralph (2000) simulations reported by Ellis and Monaghan (2002). Analogues of AoA and word frequency were created by entering patterns early or late into training with high or low frequency. Regularity was also simulated with 'consistent' or 'regular' patterns being a perfect match between input and output and 'exception' or 'irregular' patterns a mismatch between input and output patterns. An interaction between AoA and regularity was found with AoA affecting only the irregular patterns.

The 'arbitrary-connections' account of AoA (Ellis & Lambon Ralph, 2000) also predicts reduced AoA effects on word reading in languages with regular spelling-to-sound systems. In regular languages such as Italian or Spanish, every sound is represented by its corresponding letter (with very few exceptions). This regularity makes the pronunciation of a word highly predictable from its orthographic form. According to Ellis and Lambon Ralph (2000), 'predictable' connections are not likely to show AoA effects, therefore word reading in regular languages should be less influenced by the AoA variable.

However, Brysbaert, Lange et al. (2000) and Colombo and Burani (2002) reported AoA effects in the reading times of two regular languages, Dutch and Italian. These results conflict with the Ellis and Lambon Ralph's (2000) AoA account and Monaghan and Ellis's (2002a, 2002b) findings. Brysbaert, Lange et al. (2000) carried out an immediate word naming experiment in which three lists of words were created. Each list manipulated one of three variables (AoA, word frequency, and imageability) while controlling for the other two. A significant AoA effect of 11 ms was found. Word frequency also affected word naming latencies whereas imageability did not exert any effect. In order to rule out the possibility of a confounded effect of articulation with the AoA effect a delayed naming task was also completed. The 7 ms difference between early and late names was not significant. However, despite the statistical insignificance 7 ms may be a great difference when the size of the AoA effect is reduced to 11ms.

Brysbaert, Lange et al. (2000) speculated that the AoA effect might emerge from the semantic representations. They based this argument on the fact that a high correlation is normally found between AoA and imageability and in the AoA effect found in a word association task (Van Loon Vervoon, 1989). However, it remains to be explained why in Brysbaert, Lange et al.'s (2000) study AoA, a presumed semantic variable, affected word reading times whereas imageability did not.

Colombo and Burani's (2002) study involved the immediate naming of 99 Italian words (50 nouns and 49 verbs). The reaction times were entered into a series of hierarchical regression analysis. Word frequency and word length were introduced first into the analysis and emerged as significant predictors of Italian word naming times. AoA accounted for a significant 5.10% of the variance only when it was entered before context availability. When AoA was entered last, context availability (ease with which a word is evoked in a sentence context) exerted a significant effect whereas AoA did not. Colombo and Burani (2002) interpreted these results as AoA and context availability having an equivalent contribution to word naming times emerging perhaps from a shared semantic locus.

The studies reviewed above reveal that the AoA effect in word naming is still controversial. Ellis and Lambon Ralph's (2000) account of AoA is consistent with some findings (Monaghan & Ellis, 2002a, 2002b) but it conflicts with the results of other studies (Brysbaert, Lange, et al., 2000; Colombo & Burani, 2002).

In Chapter Five the AoA effect was explored in the word reading times of Spanish and English. Spanish is a highly consistent language with almost one-to-one correspondences between letters and sounds. The 25 letters of the Spanish alphabet translate into 29 phonemes, leaving room for very few grapheme-phoneme exceptions. In Spanish no letter is converted into more than two sounds and no sound is represented by more than two different letters. English spelling however, is inconsistent with a complex letter-to-sound mapping system. In English one sound can be represented in an average of 14 different ways and in turn letters can be also pronounced in several ways. For instance, 14 different representations have been detected for the sound /sh/ (e.g., shoe, sugar, issue, nation, ocean, fuchsia, etc.) and as many as 29 representations for the sound /u/ (e.g., rule, manoeuvre, group, grew, move, moon, etc.).

According to Ellis and Lambon Ralph's (2000) AoA account English would be a language with more 'arbitrary' connections between word forms and pronunciations and therefore more prone to show AoA effects. Spanish, however, would be a language with 'predictable' connections. Late acquired words would benefit from these consistent links and consequently AoA will not affect word reading in Spanish. Some approaches have detected consistent spelling to sound correspondences in English. Groups of words with equal endings and rhyme have been considered regular or consistent words. However, Monaghan and Ellis (2002a) found a significant AoA effect on the word reading times of this type of words. They interpreted the AoA effect as arising from the unpredictability of the pronunciation of consistent words. In their example, 'deal', is a late acquired consistent word (because all words ending in 'eal' rhyme) but the vowel combination 'ea' can receive different pronunciation in other words (e.g., 'head' or 'great').

Although more emphasis is given to Ellis and Lambon Ralph's (2000) AoA account, larger AoA effects in English than in Spanish might also be also predicted by the lexical account of AoA (Barry et al., 2001). That is because English words will tend to be read via a lexical route while Spanish words could be read safely via a sublexical spelling to sound route.

According to the semantic account (Brysbaert et al., 2000; Colombo & Burani, 2002) the AoA effect emerges from the quality of the semantic representations. This effect does not seem to depend on the regularity of the language since AoA effects were found in the word naming times of Dutch and Italian, both regular languages. If this is the case, and if semantic representations are consulted when reading words aloud, then it would be possible to observe AoA effects in the word naming latencies of Spanish and English.

In Chapter Five the AoA effect was explored in the word reading times of Spanish and English as first languages and of English as a second language. The stimulus words used in Experiment 7 and 8 were translation equivalents of each other (in Spanish and English) with the same AoA values in L1 and L2. For example if 'manzana' was used in the Spanish word reading task, its translation equivalent 'apple' was used in the English word reading task with the criteria that both words were acquired early in Spanish and in English.

5.2 Experiment 7 – AoA and word reading in Spanish-English bilinguals

5.2.1 Method

5.2.1.1 *Participants*

Twenty dominant Spanish-English bilinguals (6 males and 14 females) with a mean age of 23 years (range 22-33 years) who had learned English as a second language took part in the experiment. The mean age at which they started learning English was 10 years (range 8-13 years) and they had been learning English for a mean time of 13 years (range 7-20 years). They were all in their 4th and 5th year of the degree in English Philology at the University of Oviedo, Spain, where Experiment 7 was conducted.

5.2.1.2 *Materials*

Two sets (A and B) with 64 words each were created. Each set consisted of a list of 32 Spanish words (half early acquired and half late acquired words) and a second list of 32 English words (half early acquired and half late acquired words). Therefore, a total of four lists (two in set A and two in set B) were produced. The words in set A were the translation equivalents of the words in set B. Each participant read one of the two sets of words (A or B). Translation equivalents were not included within sets.

The lists manipulated AoA across the first and second languages of Spanish-English bilinguals. That is, if a word was early acquired in English as a second language, its translation equivalent counterpart was also early acquired in Spanish as a first language and the same criterion was applied for late acquired words. Early acquired in Spanish as a first language equated to an estimated learning age of less than four years and two months, while late acquired in Spanish as a first language equated to an estimated learning age of four years and four months or more. Early acquired in English as a second language meant that the word was learnt within the first two years and seven months of studying English whereas late acquired in English as a second language meant that the word was learned at the second year and eight months of studying English or later. Early and late acquired words were matched in word frequency, word length, and as far as possible on imageability, and number of neighbours. Cognates (words with similar form and meaning across languages) were not included as experimental stimuli.

The Spanish AoA values were taken from Cuetos et al. (1999). AoA in English as a second language and imageability values were taken from Izura and Ellis (2002). English word frequency values were taken from the Celex database (Baayen et al., 1993). Spanish word frequency values were taken from Alameda and Cuetos (1995). English imageability values were taken from Morrison et al. (1997).

Mean, standard deviations and range of values for each variable are shown in Table 5.1. The items and their characteristics are shown in Appendix 6.

		L2 AoA	L1 AoA	L2 Freq	L1 Freq	L2 Imag	L1 Imag	L2 N	L1 N	L2 Syll	L1 Syll
Set A											
	M	19.69	3.17	1.29	1.42	6.47	6.42	0.91	0.72	1.31	2.38
Early	SD	4.68	0.43	0.51	0.51	0.38	0.53	0.53	0.34	0.60	0.50
	Min	12.00	2.45	0.00	0.65	5.60	5.43	0.00	0.00	1.00	2.00
	Max	27.00	4.20	1.91	2.45	6.90	6.99	1.48	1.32	3.00	3.00
	M	39.76	5.38	1.33	1.28	5.51	6.11	0.60	0.55	1.44	2.63
Late	SD	7.62	1.01	0.47	0.53	1.38	1.02	0.50	0.32	0.63	0.62
	Min	27.79	4.40	0.78	0.54	2.60	3.12	0.00	0.00	1.00	2.00
	Max	52.80	7.75	2.26	2.58	6.90	6.96	1.41	1.15	3.00	4.00
Set B											
	M	17.33	3.61	1.38	1.42	6.43	6.67	0.82	0.76	1.31	2.50
Early	S	4.24	0.42	0.57	0.35	0.50	0.29	0.43	0.39	0.48	0.52
	Min	12.00	2.75	0.02	0.48	5.80	5.92	0.30	0.00	1.00	2.00
	Max	24.60	4.15	2.43	1.85	6.90	6.99	1.48	1.38	2.00	3.00
	M	42.57	5.38	1.27	1.31	5.79	5.86	0.76	0.58	1.44	2.56
Late	S	7.17	0.95	0.43	0.43	1.28	0.82	0.48	0.31	0.51	0.81
	Min	29.65	4.38	0.78	0.85	2.80	4.25	0.00	0.00	1.00	2.00
	Max	54.75	7.05	2.37	2.43	6.95	6.91	1.34	1.11	2.00	5.00

Table 5.1 Mean (M), standard deviation (S) and maximum (Max) and minimum (Min) values for the variables controlled in Experiment 7. Note: AoA = age of acquisition, Freq = word frequency, Imag = imageability, N = number of orthographic neighbours, Syll = number of syllables.

5.2.1.3 *Procedure*

The stimuli were presented in the centre of a computer screen in black 48 lowercase print using New York font. The screen was approximately 60 cm away from the participant. A fixation dot of 1000ms duration was followed immediately by the stimulus word. Words remained on the screen until participants made a response, whereupon a 500ms blank appeared before the presentation of the next fixation dot. Verbal responses triggered a voice key linked to a high-sensitivity microphone worn by each participant. Participants were instructed to read each word aloud as quickly and as accurately as possible. Participants were aware that the experiment consisted of two phases one to read words in Spanish and the other to read words in English. The language order was counterbalanced. Presentation of the items and recording the reaction times was controlled by the SuperLab experiment generator package (Abboud, 1991). Twenty words were presented at the beginning of the experiment for practice.

5.2.2 Results

Only correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Six responses (0.47%) fell outside 3.5 standard deviations and were removed from reaction times analyses. An additional 90 responses (7.03%) to words were errors that involved mispronunciations or hesitations.

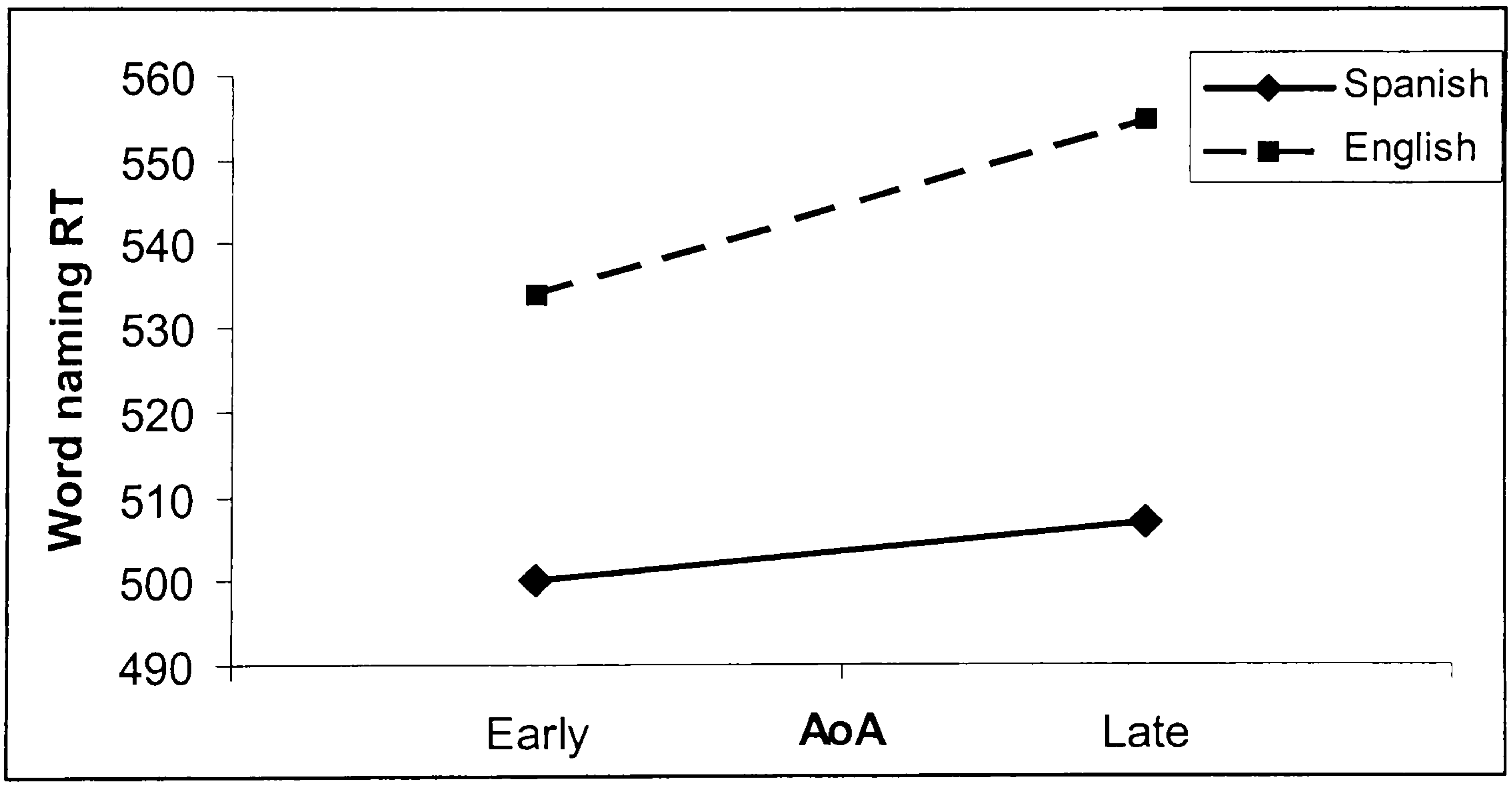
Mean reaction times, standard deviations and percentage of errors are shown in Table 5.2

		Spanish		English	
		Early	Late	Early	Late
RT	M	500	507	534	555
	S	77	80	67	80
% errors		2.66	2.66	4.38	4.06

Table 5.2 Mean RT (M), standard deviations (S) and percentage of errors (%) in word reading in Spanish as a first language and in English as a second language in Experiment 7.

5.2.2.1 *Reaction time analysis*

An analysis of variance was carried out on naming latencies. The main effect of language was significant, $F_1(1, 19) = 9.93$, $MSE =$ 34074.58, $p < 0.05$; $F_2(1, 128) = 47.69$, $MSE =$ 54.370.83, $p < 0.001$, with participants being faster at reading words in L1 (Spanish) than in L2 (English). The main effect of AoA was also significant, $F_1(1,19) =$ 6.39, $MSE =$ 3852.67, $p < 0.05$, $F_2(1, 128) = 6.38$, $MSE =$ 3852.67, $p < 0.05$, with early acquired words being read faster than late acquired words. The difference between sets was not significant, $F_1(1, 18) = .24$, $MSE =$ 2437.52, $p > 0.1$; $F_2(1, 128) = 2.77$, $MSE = 3162.31$, $p > 0.05$. The interaction between AoA and sets was significant only in the analysis by items, $F_2(1, 128) = 4.14$, $MSE =$ 4715.91, $p < 0.05$, with an overall larger effect of AoA in set A than in set B. The interaction between sets and language was significant in the analysis by items only, $F_1(1,19) = 1.04$, $MSE = 3582.23$, $p > 0.1$; $F_2(1, 128) = 6.73$, $MSE = 7266.75$, $p < 0.05$, with English word reading times faster in set A than in set B. Most importantly, the interaction between AoA and language approached significance in the analysis by subjects, $F_1(1, 19) = 3.52$, $MSE = 1020.95$, $p = 0.07$; $F_2(1, 128) = 1.31$, $MSE = 1496.05$, $p > 0.1$, suggesting a stronger AoA effect in English than in Spanish. The form of the interaction is shown in Figure 5.1. This was further assessed with two t-tests in which the AoA effect was observed in English, $t_1(19) = -2.71$, $p < 0.05$; $t_2(31) = -2.44$, $p < 0.05$, but not in Spanish, $t_1(19) = -$



1.11, $p > 0.1$, $t_2(31) = -1.41$, $p > 0.1$.

Figure 5.1 The interaction between AoA and language in Experiment 7.

A percentage increase effect was obtained dividing the size of the AoA effect by the average reading time for early acquired words then multiplying by 100. The percentage increase from early to late acquired words was greater for English (3.90%) than for Spanish (1.40%).

Since imageability and number of neighbours (N) have been claimed to affect word reading times and the control of these variables in Experiment 7 was not precise, the two variables were covaried to assess their contribution on word reading times.

In Experiment 7 the straightforward by-items analysis showed a main effect of AoA. When imageability was entered as a covariate the AoA effect approached significance, $F_2(1,128) = 3.61$, $MSE = 4077.13$, $p = 0.06$, but the imageability effect was not significant, $F_2(1, 128) = 2.21$, $MSE = 2493.83$, $p > 0.1$. When N was entered as a covariate the AoA effect remained significant, $F_2(1, 128) = 4.40$, $MSE = 4746.32$, $p < 0.05$, and the N effect was also significant, $F_2(1, 128) = 7.86$, $MSE = 8478.08$, $p < 0.05$. The interaction between AoA and language did not approach significance in any of the covariate analysis of items.

5.2.2.2 *Error analysis*

The low number of errors precluded the use of analysis of variance. Analysis of the error rates using the Wilcoxon matched-pairs signed-ranks test showed that AoA was not affecting the accuracy of word reading in Spanish as a first language, $Z = -.36$, $p > 0.1$, or English as a second language, $Z = -.59$, $p > 0.1$.

5.2.3 Discussion

The results of Experiment 7 showed an AoA effect in English as L2 word reading with early acquired words named faster (534ms) than late acquired words (555ms). AoA, however, did not influence Spanish word reading as much as English word reading (500ms for early acquired words versus 507ms for late acquired words). The interaction between AoA and language only approached significance. Since the AoA effect in English word reading interacts with consistency with larger AoA effects for irregular words than for regular words (Monaghan & Ellis 2002a, 2002b) it is conceivable to think that cross language comparisons will be affected by the proportion of irregular words included in the English word reading task. Besides, the difference observed between early and late acquired words in English (21ms) was much larger than in Spanish (7ms). Consequently, the main effect of AoA found in Experiment 7 was mainly driven by the AoA differences found in English. This was confirmed by the results of the t-tests analyses where the AoA effect was observed in English but not in Spanish reading times. These results are consistent with Monaghan and Ellis's (2002a, 2002b) findings and with the prediction of an AoA effect on English word reading times but not on Spanish word reading times.

The different size in the AoA effects for Spanish and English does not support the semantic account of AoA. If AoA is a property of the semantic representations and these are shared between the two languages of a bilingual then the same or similar AoA effects should be observable for L1 and L2. The results of Experiment 7 reveal that this was clearly not the case.

However, some authors (Dijkstra et al., 1999; Jared & Kroll, 2001) have pointed out that recognition and naming of L2 words is affected by the phonological characteristics of L1. Thus, it is conceivable that the large AoA effect found in the naming times of L2 words was confounded by a competition effect between the different grapheme to phoneme conversions of L1 and L2. This idea was further explored in Experiment 8.

5.3 Experiment 8 – AoA and word reading in Spanish-English bilinguals and English monolinguals

5.3.1 Introduction

Jared and Kroll (2001) pointed out that word reading times in the bilingual's second language are influenced by the spelling-sound correspondences of their first language. In a series of experiments, French-English bilinguals named blocks of words in French and/or in English. Spelling to sound influences in L1 word reading were observed only when participants read words in both English and French at the same time, but not when they read words exclusively in the first language. However, second language word reading was influenced by the spelling-sound correspondences of L1 invariably when participants read words only in L2 and when they read words in both languages.

Participants in Experiment 7 were dominant Spanish-English bilinguals with Spanish as their first and dominant language and English as their second language. One possible criticism of Experiment 7 is that word reading in L2 (English) was influenced by the competition between the different spelling to sound correspondences of L1 and L2. The AoA effect found could have been confounded by this competition effect.

Experiment 8 explored the AoA effect on Spanish and English word naming times with a group of Spanish-English bilinguals and an English monolingual control group. In Experiment 8 an effort was made to create bigger lists of stimuli with a better control of variables than in Experiment 7. AoA was manipulated across languages in such a way that if a word was early acquired in Spanish as L1, it was also early acquired in English as L1 and as L2. The same rule was applied to late acquired words. The predictions were the same as in Experiment 7, if the AoA effect resides in the nature of the connections between representations a much larger AoA effect would be observed for English than for Spanish. If on the other hand, AoA emerges from the quality of the semantic representations themselves then a similar AoA effect would be expected in English and Spanish word reading times.

5.3.2 Method

5.3.2.1 *Participants*

Fifteen native English speakers and thirty native Spanish speakers (20 males and 25 females) with a mean age of 26 (range 18-38 years) took part in the experiment. None of the English participants reported to be bilingual, though all of them considered themselves to have basic knowledge of German or French. Spanish participants were native speakers of Spanish that had been living in England for a mean time of 2 years (range 4 months-8 years). They had started to learn English at a mean age of 13 years (range 9-22 years) and had been learning English for a mean time of 11 years (4-23 years).

5.3.2.2 *Materials*

Stimuli consisted of two lists (one in English and one in Spanish) of 40 words each. Each list consisted of 20 early and 20 late acquired words. Words in the Spanish list were the translation equivalents of the words in the English list and vice-versa. The AoA of the words was the same across languages if they were L1 or L2. Therefore, early acquired words in Spanish as L1 (e.g., barco) were also early acquired words in English as L1 (e.g., boat) and in English as L2. Similarly late acquired words in Spanish as L1 (e.g., alma) were also late acquired in English as L1 (e.g., soul) and in English as L2. AoA values for Spanish as L1 and English as L2 were taken from Cuetos et al. (1999) and Izura and Ellis (2002).

New AoA ratings were collected for English as L1 following the same procedure as Morrison et al. (1997). Fifteen native English participants (4 males and 11 females) with a mean age of 21 years (range 18-21 years) completed the rating scale and did not participate in the word reading experiment. They were asked to rate 100 words on a 7-

point scale as to when they believed they and others had acquired each word. The scale ranged from 1= learned before the age of 2, through 2= learned between the 2 and 3 years of age to 7= learned at the age of 13 or older. Eighty of the 100 words had previously been rated (Morrison et al., 1997). The correlation between the ratings for those 80 items was $r = 0.94$.

None of the words used in Experiment 8 were cognates (equal in form and meaning). Words were matched on word frequency (Celex: Baayen et al., 1993; Alameda & Cuetos, 1995), word length, number of neighbours and as far as possible on imageability. Unlike Experiment 7, word length was measured as the number of letters in the word instead of the number of syllables.

Mean, standard deviation and range of values for each variable are shown in Table 5.3. The items and their characteristics are shown in Appendix 8.

		En L1 AoA	En L2 AoA	Sp L1 AoA	En Freq	Sp Freq	En Imag	Sp Imag	En N	Sp N	En Let	Sp Let
	M	1.76	18.81	3.49	1.28	1.31	6.52	6.47	0.84	0.60	4.50	5.65
Early	S	0.27	4.26	0.41	0.59	0.42	0.28	0.47	0.46	0.33	1.05	1.42
	Min	1.25	12.60	2.45	0.00	0.48	5.80	5.43	0.00	0.00	3.00	3.00
	Max	2.25	24.60	4.20	1.93	1.98	6.89	6.99	1.48	1.32	7.00	8.00
	M	3.29	41.52	5.43	1.28	1.40	5.54	5.76	0.68	0.66	5.05	6.00
Late	S	0.85	7.13	0.95	0.45	0.46	1.32	0.95	0.51	0.31	1.50	1.12
	Min	2.31	27.79	4.40	0.78	0.78	2.60	3.12	0.00	0.00	3.00	4.00
	Max	5.38	53.33	7.75	2.37	2.58	6.95	6.96	1.34	1.15	8.00	8.00

Table 5.3 Mean (M), standard deviation (S), maximum (Max) and minimum (Min) values for the variables controlled in Experiment 8. Note: En = English, Sp = Spanish, L1 = first language, L2 = second language, AoA = age of acquisition, Freq = word frequency, Imag = imageability, N = number of orthographic neighbours, Let = number of letters.

5.3.2.3 *Procedure*

The experiment was carried out using a Macintosh Centris AV - 600 computer. Participants sat facing the computer screen, which was about 60cm in front of them. Each trial began with a fixation dot of 1000ms duration followed immediately by the stimulus word. The computer screen then went blank for 500ms before the next trial began. Words remained on the screen until participants made a response. Verbal responses triggered a voice key linked to a high-sensitivity microphone worn by each participant. The words were presented in the middle of the screen in lowercase using 48-point New York font.

The 30 bilingual participants were split into two groups of 15 individuals each. One bilingual group read words in Spanish and the other bilingual group read words in English. The third group of 15 monolingual native speakers of English read words in English.

The instructions were written down in English for the English word reading and in Spanish for the Spanish word reading task. Instructions informed participants that words would appear one at a time in the centre of the screen and that they had to read them aloud as quickly and accurately as possible. They were also advised to say only the target word and that mispronunciations or verbal hesitations would invalidate the response. Twenty practice words were included at the beginning of the experiment to familiarise participants with the task.

5.3.3 Results

Only correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. One response (0.16%) to Spanish words and 7 responses (0.58%) to English words fell outside 3.5 SD and were removed from further analysis. An additional 9 responses (1.50%) to Spanish word reading and 48 responses (4.00%) to English words reading were errors that involved mispronunciations or hesitations. Errors were removed from RT analysis.

Table 5.4 shows the mean RT, standard deviations and error rates for the three groups of participants.

			English L1	English L2	Spanish L1
Early	RT	M	501	633	491
		S	49	68	31
	% error		0.66	6.66	1.33
Late	RT	M	517	657	493
		S	46	80	35
	% error		1.66	7.00	1.66

Table 5.4 Mean RT (M), standard deviation (S) and percentage error (% error) in Experiment 8 (word reading).

5.3.3.1 *Reaction time analysis*

By-subjects and by-items analyses of variance were carried out, with language (English L2 and Spanish L1) and AoA as factors. The main effect of language was significant, $F_1(1,28) = 52.67$, $MSE = 340484.07$, $p < 0.001$; $F_2(1, 38) = 531.47$, $MSE = 455766.36$, $p<0.001$, with word reading times faster in Spanish as a first language (492 ms) than in English as a second language (509 ms). The main effect of AoA was significant in the analysis by subjects and by items, $F_1(1, 28) = 16.82$, $MSE = 3255.33$, $p<0.001$; $F_2(1,38) = 3.88$, $MSE = 4050.71$, $p=0.05$, with RTs being faster to early acquired words than to late acquired words. Importantly, the interaction between language and AoA was significant in the analysis by subjects, $F_1(1, 28) = 6.40$, $MSE = 1237.70$, $p< 0.05$, though not in the by-items analysis, $F_2(1,38) = 1.55$, *MSE* = 1325.19, p>0.1. Separate t-tests analyses of RTs in Spanish and English showed that for the Spanish-English bilingual group reading Spanish words AoA was not significant, $t_1(14) = -.33$, $p > 0.1$, while for the Spanish-English bilingual group reading English words the effect of AoA was significant, $t_1(14) = -4.27$, $p<0.001$.

Another analysis of variance was carried out with AoA and language (English L1 and Spanish L1) as factors. The main effect of AoA was significant in the analysis by subjects, $F_1(1, 28) = 8.24$, *MSE* = 1267.95, p<0.05, and approached significance in the analysis by items, $F_2(1,38) = 3.50$, *MSE* = 2532.15, p=0.069, with faster reading times for early acquired words than for late acquired words. The main effect of language was significant in the analysis by items only, $F_1(1, 28) = 1.34$, *MSE* = 4282.80, p>0.1; $F_2(1,38) = 1.08$, *MSE* = 532.62, p<0.05, with faster reading times in Spanish as a first language than in English as a first language. The interaction between AoA and language was significant only in the analysis by subjects, $F_1(1, 28) = 5.52$, *MSE* = 850.36, p<0.05; $F_2(1,38) = 1.08$, *MSE* = 532.62, p>0.1. Separate t-tests analyses of RT in Spanish and English showed that for the Spanish-English bilingual group reading Spanish words AoA was not significant, $t_1(14) = -0.33$, $p > 0.1$, while for the English monolingual group reading English words the effect of AoA was significant, $t_1(14) = -4.06$, $p<0.001$. The percentage increase from early to late acquired words was greater for English whether this was L1 (3.20%) or L2 (3.80%) than for Spanish (0.40%).

5.3.3.2 *Error analysis*

The low number of errors precluded the use of analysis of variance. Analysis of the error rates using the Wilcoxon matched-pairs signed-ranks test showed that AoA did not exert an influence on the accuracy at which English native speakers read words aloud, $Z = -1.13$, $p>0.1$. The AoA effect was not found either when Spanish-English bilinguals read words in Spanish or English, $Z = -0.45$, $p>0.1$; $Z = -0.30$, $p>0.1$.

5.3.4 Discussion

Experiment 8 showed that native speakers of English read early acquired words significantly faster than late acquired words. This result is consistent with previous findings of an AoA effect on English word reading latencies (Coltheart et al., 1998; Gerhand & Barry, 1998; Monaghan & Ellis, 2002; Morrison & Ellis, 1995, 2000) and suggests that the AoA effect found in Experiment 7 for English as a second language was not due to the possible competition between grapheme-phoneme correspondences of L1 and L2. However the AoA effect did not come into play when native speakers of Spanish read aloud words in Spanish. This finding contradicts the AoA effects reported by Brysbaert, Lange et al. (2000) for Dutch and by Colombo and Burani (2002) for Italian.

5.4 Experiment 9 – Delayed word naming

Experiment 9 was conducted as a control experiment to test whether the results of Experiment 8 could have been confounded by the effect caused by the articulation of the initial sound of the words. Kessler, Treiman, and Mullennix (2002) found that the pronunciation of words beginning with voiced letters triggered voice keys faster than the pronunciation of voiceless letters. This initial sound effect can interfere with the effect under observation in any task involving the production of words. Therefore, in Experiment 9 two delayed word naming tasks were completed. The tasks involved the Spanish and English stimuli used in Experiment 8 and were completed by Spanish and English native speakers.

5.4.1 Method

5.4.1.1 *Participants*

Eight native English speakers and eight native Spanish speakers (9 males and 7 females) with a mean age of 28 (range 24-35 years) took part in the experiment. Only one of the English participants reported to be English-Spanish bilingual with Spanish as the second language. All Spanish participants were native speakers of Spanish with English as a second language.

5.4.1.2 *Materials*

The experimental stimuli used in Experiment 9 consisted of the same experimental words used in Experiment 8. Sixty-four filler items were included and cued at different delays in order to avoid cue predictability.

5.4.1.3 *Procedure*

The experiment was carried out using a Macintosh Centris AV - 600 computer. Participants sat facing the computer screen, which was about 60cm in front of them. Each trial began with a fixation dot of 1000ms duration followed immediately by the stimulus word. The cue to respond was the appearance of the word between brackets. Once the brackets appeared the word remained on the screen until the participant responded. The cue for experimental items was set at 1000ms. Two additional sets of 32 filler items each were added and were cued after a delay of 600ms and 1400ms respectively. Once a response was made the next trial began with the next fixation dot in the middle of the screen. Verbal responses triggered a voice key linked to a high-sensitivity microphone worn by each participant. The words were presented in the middle of the screen in lowercase using 48-point New York font.

The 8 Spanish native speakers completed the delayed naming task in Spanish while the 8 English native speakers completed the delayed naming task in English.

Instructions informed participants that words would appear one at a time in the centre of the screen and that they had to read them aloud as soon as they appeared between brackets. They were also advised to say only the target word and that mispronunciations or verbal hesitations would invalidate the response. Eighteen practice words were set at 1000ms, 600ms and 1400ms delays and were included at the beginning of the experiment to familiarise participants with the task.

5.4.2 Results and discussion

Only correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Overall, two responses (0.16%) fell outside 3.5 SD and were removed from further analysis. An additional 2 responses (0.62%) to Spanish delayed reading and 2 responses (0.62%) to English delayed reading were errors that involved word naming before the word appeared between brackets. Errors were removed from further analyses.

Table 5.5 shows the mean RT, standard deviations and error rates for the two delayed naming tasks.

			English	Spanish
Early	RT	M	349	364
		S	60	60
	% error		0.66	0.66
Late	RT	M	343	361
		S	67	60
	% error		0	0

Table 5.5 Mean (M), standard deviation (S) and percentage of error (% error) in Experiment 9 (delayed word naming).

The AoA effect on Spanish delayed naming was not significant, $t_1(7) = 0.41$, p>0.1, $t_2(19) = 0.28$, p>0.1. No significant AoA effect was found on English delayed naming, $t_1(7) = 1.09$, p<0.1, $t_2(19) = 0.57$, p>0.1. These results suggest that for the stimuli used in Experiment 8 and 9, the speed at which initial sounds triggered the voice key in Experiment 8 did not interfere with the effects found on immediate word naming.

5.5 General Discussion

Experiment 7 and 8 compared the performance of Spanish and English word reading. The aim was to observe how the AoA of both languages affects reading times. In Experiment 7 the performance of a group of bilinguals reading words in English (L2) and in Spanish (L1) was examined. In Experiment 8 data were collected from a bilingual group similar to that of Experiment 7 and a monolingual English group.

The main results of these experiments showed that AoA affects word reading times in English, whether English is the first or the second language, but not in Spanish. Experiment 9 was created to control for any possible articulation effects due to initial sound differences between early and late acquired words. The results revealed that the effect of initial phonemes on the articulation of the words used in Experiment 8 did not influence the AoA effect found in English word reading.

The semantic account of the AoA effect (Brysbaert, Lange et al., 2000; Colombo & Burani, 2002) that locates the AoA effect on the quality of the semantic representations does not explain the asymmetric AoA effect found across languages in Experiment 7 and 8. If it was the case that early acquired meanings could somehow be better represented than late acquired meanings, and semantic representations are consutlted when reading in regular and irregular languages, then an AoA effect would be expected irrespective of the language. In addition, assuming that meanings are shared between the two languages, similar AoA effects would be expected in L1 and L2. Translation equivalents with equal AoA values in both languages were used. Therefore the same meanings were activated when participants read in English (L2) or in Spanish (L1) as a consequence similar AoA effects would have to be observed. This was clearly not the case.

The results from Experiments 7 and 8 are better explained in terms of the AoA account proposed by Ellis and Lambon Ralph (2000). They suggested that the AoA effect depends on the nature of the connections between representations. Arbitrary connections such as those formed between English word forms and their pronunciations are likely to create AoA effects since late acquired items can not get any benefit from early acquired items. However, predictable connections such as those formed when learning to read Spanish words are less prone to produce AoA effects since late acquired words can make use of the knowledge acquired when the first words were learned. The results of Experiment 7 and 8 are in accordance with these predictions. Early acquired words were read faster than late acquired words in English, a language with irregular spelling to sound connections. However, no differences between early and late acquired words were found for Spanish, a language with regular grapheme-phoneme correspondences.

Similar results were obtained in Monaghan and Ellis's (2002a, 2002b) studies where AoA and English consistency were orthogonally manipulated. Consistent or regular words are words that shared the same orthographic ending and rhyme. Exception or irregular words belong to word families that shared the same orthographic ending but not rhyme. Monaghan and Ellis (2002a, 2002b) found an interaction between consistency and AoA with a larger AoA effects on irregular than on regular words.

Finally, the lexical account of AoA (Barry et al., 2001) can also explain the results found in Experiments 7 and 8. If reading words in regular languages such as Spanish is accomplished via a sublexical (spelling-to-sound) route then lexical variables such as AoA would not have the opportunity to influence Spanish word reading. However, as English is more irregular than Spanish there would be a tendency, at least for some words, to be read via the lexical route where AoA may exert its influence.

CHAPTER SIX

AGE OF ACQUISITION EFFECTS IN WORD TRANSLATION

6.1 Introduction

Chapter Six explored the possible influence of age of acquisition (AoA) on the speed of making translation judgements. In this Thesis AoA has been shown to affect the speed of processing in L1 and L2 in a variety of tasks. For example, in Chapter Three early learned words were produced as names in L1 and L2 faster than later learned words. Similarly, early words in both languages were responded more quickly in the lexical decision tasks in Chapter Four. Chapter Five showed that AoA affects word reading latencies in English as first language (L1) and as a second language (L2) but not in Spanish as L1.

The results presented in Chapters Three, Four and Five have suggested that the AoA effect could emerge from the connections between representations or from the lexical representations themselves but not from the semantic level. This is because L2 AoA exerts an independent effect from L1 AoA in object naming, word naming and lexical decision latencies. If L1 and L2 share the same semantic representations only L1 AoA effects would be expected.

However, a postulated location for the AoA effect has been the semantic representations. Lyons et al. (1979) were the first to suggest that if words represent concepts it could be that AoA effects reflect the relationship between the order of concept acquisition and the availability of such concept. More recently Steyvers and Tenenbaum (2002) have implemented AoA effects in a semantic network. They entered a number of abstract 'nodes' (concepts) over time (cumulatively) into the network. In the growing process of the model connections are introduced between new nodes and existing nodes. They showed an analogy of the AoA effect in terms of the 'conectivity' of the network with older nodes (early concepts) holding more connections than younger nodes (late concepts).

The influence of AoA on human semantic processing has been more problematic to prove. Morrison et al. (1992) carried out an experiment in which participants classified 58 objects as belonging to one of two categories: man-made objects or natural occurring objects. No AoA effect was found leading them to suggest that AoA affects name retrieval rather than semantic processing.

Brysbaert, Van Wijnendaele et al. (2000) explored the semantic nature of the AoA effect using two tasks: a word association task and a semantic classification task where participants had to decide if 288 words were first names or a word with a definable meaning. They found longer reaction times to produce associates to words that were late acquired low frequency and low imageability. It was also demonstrated that AoA and word frequency affected the semantic classification task. The fact that the production of words was not required on the semantic categorisation task and the reported absence of phonological effects in the same categorisation task by Taft and Van Graan (1998) lead Brysbaert, Van Wijnendaele et al. (2000) to suggest that the AoA effect observed emerged from the semantic representations. They concluded, "order of acquisition remains the most important organising factor of the semantic system" (pp.224), leaving open the possibility of AoA emerging from one or multiple locations. However, Brysbaert, Van Wijnendaele et al.'s (2000) results might have another interpretation. It is conceivable that the categorisation processes involved in deciding whether a word is a first name or a definable word are not only semantic but also lexical processes. Hence, as Brysbaert, Van Wijnendaele et al. (2000) pointed out, the lexeme or phonological representations could have been accessed and if so also the lemma representations could have been activated. Similarly it could be argued that the connections between lexical and semantic representations were actively playing a role in the completion of the task.

As a consequence the semantic nature of the AoA remains unclear. Available data regarding AoA effects on semantic processing are scarce. One possible reason for the lack of studies in this area is the difficulty at finding a semantic task where any trace of AoA effects could be unmistakable attributed to the semantic representations.

In the present Chapter the AoA effect was examined in word translation, a semantic task that, thanks to the specific characteristics of the bilinguals who participated in the study, can tell whether AoA is or is not a property of the semantic representations. Also, the semantic nature of the translation task would alow us to tell with certainty whether AoA affects not only word production and word recognition but also word comprehension. To date word naming and lexical decision tasks have shown effects of AoA (Brysbaert, Lange, et al., 2000; Cirrin, 1984; Gerhand & Barry, 1998; Gilhooly & Logie, 1981a; Turner et al., 1998).

Both tasks require the comprehension of some but not every word. For instance, regular words in English can be read through the grapheme-phoneme conversion mechanism without need of semantic processing. Similarly, deciding if a letter string is a word or a nonword can be based exclusively on the orthographic or phonological familiarity of the word depending on the nature of the nonwords. In addition, robust AoA effects have been found in the lexical decision task, although the influence of AoA on word reading is currently a matter of debate.

In the word translation task all the words need to access their semantic representation/s in order to be translated. That is, in the translation task all the words have to be comprehended. Would AoA affect word comprehension?

Most researchers (Potter et al., 1984; La Heij, Hooglander, Kerling, Van-Der Velden, 1996; Snodgrass, 1993) consider translation to be a semantic task, arguing that a word in one language has to be recognised and comprehended in order to be translated into the other language. However, Kroll and Stewart (1994) cast some doubt about the semantic nature of word translation. A series of studies (Kroll & Curley, 1986; Kroll & Stewart 1994) found that non-fluent bilinguals took less time to translate words from the second (L2) to the first (L1) language than from L1 to L2. Kroll and Stewart (1994) argued that this asymmetry is due to the extra semantic step required to translate in one direction (from L1 to L2) but not in the other (from L2 to L1). Kroll and Stewart (1994) proposed the revised hierarchical model (RHM Figure 1.3, pp. 30) that combined in one two pre-existing models of bilingual lexical representation; the word association model and the concept mediation model. According to the RHM, lexical and conceptual links are created in the course of learning a second language. The strength of these connections varies depending on the fluency in L2. In general, for those bilinguals more fluent in one language than the other, the model states that word forms in L1 are strongly linked to their semantic representations and weakly connected to L2 word forms. Direct connections between words in L2 and semantics are also formed but these are weak. L2 word forms are strongly linked to word forms in L1. The lexical connections assumed by the model are bi-directional but, possibly as a result of the common practice of learning words in a new language by associating them with their translation in L1, the lexical links are stronger from L2 to L1 than from L1 to L2.

The implications of the model on translation performance are clear. The weak connections between words in L2 and semantics preclude the use of this route when translating from L2 to L1 and the strong lexical links become the favourite pathway. However, translating from L1 to L2 is accomplished via semantics since the strong connections between word forms in L1 and meaning facilitate the use of this route. Subsequent research searching for evidence to support the model has generated inconclusive results. A number of studies (Cheung & Chen, 1998; Sholl, Sankaranarayanan, & Kroll, 1995; Talamas, Kroll, & Dufour, 1999) support the translation asymmetry proposed by Kroll and Stewart (1994). Sholl et al. (1995) required participants to name a set of pictures in L1 and L2. Immediately afterwards they had to translate a set of words in L1 and L2. Half of the stimuli in the translation task were names of the pictures named previously the other half were words never seen before. The results showed that previous naming of pictures in L1 and L2 facilitated translation from L1 to L2 but not translation from L2 to L1. Sholl et al. (1995) interpreted these results as a demonstration of the translation asymmetry. Only translation from L1 to L2 is conceptually mediated, because it is the only direction of translation primed by another semantic task such as picture naming. In the same line, Cheung and Chen (1998) showed that when Chinese-English bilinguals matched words to categories, they were faster at matching L1 words than L2 words, supporting the idea that L1 has stronger conceptual connections than L2. It was also observed that translating into L2 was slower than translating into L1. Cheung and Chen interpreted these results as a confirmation of the asymmetry proposed by Kroll and Stewart's (1994) model.

Nevertheless, the model has also been challenged by a series of studies that have failed to support a lexical route when translating from L2 to L1. If anything, both directions of translation can be conceptually mediated. Altarriba and Mathis (1997), for instance, found that semantically related words affected translation recognition in the direction claimed to be lexical; that is, from L2 to L1. Similar results were obtained by Talamas et al. (1999) in a study where fluent and not-so-fluent bilinguals were slower at rejecting semantically related non-translation pairs than unrelated non-translation pairs.

In a recent review, Kroll and Tokowicz (2001) examined the apparently contradictory results. They point out that the studies that support the revised hierarchical model involved the tasks in which generation of L2 words is required (e.g., normal translation or translation production task). In contrast, the studies whose results seem to contradict the model generally involve word recognition tasks (e.g., the translation decision task). In the light of these differences, Kroll and Tokowicz (2001) argued that proficient and not-so-proficient bilinguals have little difficulty in accessing semantic information; that is, in recognising or comprehending L2 words. However, the difficulty and origin of the asymmetry proposed by the revised hierarchical model resides in the lexicalization process; that is, in the production of L2 words when naming pictures, expressing ideas or translating words.

The difficulty associated with translation production is more pronounced when translating into L2 is required from bilinguals who are not highly proficient in their second language. An alternative to the translation production task has been developed and this is the so-called translation recognition task. In this task participants have to decide if pairs of words (one in L1 the other in L2) share the same meaning or not. Unlike translation production, in the translation recognition task the difficult process of producing L2 words is avoided, allowing researchers the use of a wide range of stimuli such as low frequency, low imageability or late acquired words. The critical difference between translation recognition and translation production tasks consists precisely in the absence of word retrieval and articulation in the translation recognition task. Without word production it is difficult to establish if the lexicalization process from concepts to L2 words forms occurs or not. However, the translation recognition task still shares many features with the translation production task. De Groot and Comijs (1995) carried out a comparison between both translation tasks, showing that translation recognition is sensitive to a great extent to the same experimental manipulations as translation production. Another common feature shared between both translation tasks is their semantic nature. The semantic involvement in translation recognition has been largely demonstrated. For instance, it has been shown that bilinguals are slower at rejecting semantically related non-translation pairs than unrelated pairs (Altarriba & Mathis, 1997; Talamas et al., 1999). Other studies have found that translation recognition times where non-translation pairs are unrelated, are affected by semantic variables such as imageability (De Groot, 1992; De Groot & Comijs, 1995). However, none of these studies have controlled for AoA effects.

Translation decisions can therefore be considered as judgements about word meanings and in consequence a semantic task. Of particular relevance to the present Chapter are those studies which suggest that AoA is a fundamental characteristic of the semantic system (Brysbaert, Van Wijnendaele et al., 2000; Steyvers & Tenenbaum, 2002). If AoA is a property of the semantic representations, as Brysbaert, Van Wijnendaele et al. (2000) claimed, and if these representations are shared between the two languages of a bilingual (De Bot, 1992; Costa et al., 1999), then translation recognition latencies should be affected only by first language AoA. This is because words learned in L2 should inherit the AoA characteristics of the semantic representations of the corresponding L1 words. In contrast, if AoA is a property of lexical entries, as proposed by Gerhand and Barry (2000), or of the mappings between word-forms and semantics, as proposed by Ellis and Lambon Ralph (2000), then AoA effects might be detected in both L1 and L2, with those effects reflecting the relative order in which the words were learned in the two languages.

Translation tasks have been traditionally used as a tool to investigate bilingual lexical organisation. The majority of this research has focused on how the two languages are represented and connected and has paid little attention to differences between words in terms of their frequency, concreteness, age of acquisition, etc. However, some studies have sought to identify the characteristics of words that make translation decisions relatively easy or difficult. De Groot (1992), for example, carried out one of the studies concerned with how different attributes of the words affect translation latencies. In Experiment 3 of De Groot (1992), Dutch-English bilinguals completed a translation production task in which they were asked to translate 458 words from their first language (Dutch) to their second language (English). She found that out of 10 variables entered into a regression analysis, only four predicted word translation. These were cognate status (degree of orthographic and semantic similarity between translation equivalents), contextual availability (a measure of how easy a word evokes a sentence or a sentence fragment), the length of the target word and the frequencies of both words. Age of acquisition (AoA) was not employed in the analysis. Monolingual research has largely demonstrated that word frequency and AoA are highly correlated variables, high frequency words tend to be early acquired whereas low frequency words are acquired normally some time later. It is therefore possible that the frequency effects found in De Groot's (1992) study were partially confounded with AoA. Subsequent research has mainly focused on the importance of semantic variables amongst others in translation, suggesting that word frequency, imageability, and cognate status are relevant variables in translation production and recognition (De Groot & Comijs, 1995; Hell & De Groot, 1998). De Groot, Dannenburg, and Van

Hell (1994) showed that semantic variables such as imageability and context availability along with familiarity variables and cognate status affected not only forward (from L1 to L2) but also backward (from L2 to L1) translation. De Groot and Poot (1997) demonstrated once again that imageability (a variable even more correlated with AoA than frequency), word frequency, and cognate status influence translation production latencies in three groups of Dutch-English bilinguals varying in their degree of L2 fluency.

Murray (1986) carried out the only study I am aware of on translation performance that took AoA into account. He looked at the influence that a total of 21 independent variables had on the translation times of 145 words, among them the AoA of words in the participants' native language. Participants were dominant English-French bilinguals with English as the dominant and first language. A stepwise multiple regression analysis was carried out on the translation latencies. The results revealed that word frequency and cognate status ("similarity of English and French equivalents") affected translation in both directions, findings that have been repeated several times since (see De Groot et al., 1994; Kroll & Tokowicz, 2001). Importantly for present purposes, AoA in L1 predicted translation times only when translating into L1. It also predicted the number of errors made in translating from English into French.

There are problems with Murray's (1986) study, including the use of stepwise regression when the predictor variables were intercorrelated (cf. Morris, 1981), the lack of AoA for the French (L2) words, and the relatively small number of participants (11 translating from English to

French and 10 from French to English). Murray (1986) acknowledged that his was "essentially a first attempt to establish some of the variables influencing ease of translation" (pp. 353). The study did, however, indicate that first language AoA might be one of the factors that influences translation speed; AoA has not, however, been investigated further. It has also not been controlled in studies that have analysed the (apparent) effects of variables like word frequency and imageability that are known to correlate significantly with AoA (Gilhooly & Logie, 1980; Morrison & Ellis, 1995).

In Experiments 10 and 12, dominant Spanish-English bilinguals decided whether pair of words (one in Spanish and one in English) were or were not translations of each other. The pairs were either early acquired in both languages, late acquired in both languages, or early acquired in one language but late acquired in the other language. This manipulation of the AoA of L1 and AoA of L2 was possible since the vocabulary of L1 and L2 do not always follows the same order of acquisition (as indicated in section 4.1, pp. 108).

6.2 Experiment 10 – AoA effects on a simultaneous translation judgement task

6.2.1 Introduction

In Experiment 10 the translation recognition task was used. The AoA of the first and second languages were orthogonally manipulated in order to create four sets of translation pairs that were early or late acquired in both languages, or early acquired in one language and late acquired in the other language. The word sets were matched on word frequency, imageability, and length in both languages and on translation accuracy across languages.

6.2.2 Method

6.2.2.1 *Participants*

The participants were 20 Spanish native speakers (10 females, 10 males) born and brought up in Spain, with a mean age of 28 years (range 23-34 years) who had started to learn English after a mean age of 12 years (range 6-24 years) and they had been studying English for a mean time of 11 years (range 4 – 24 years). At the time of testing all the participants were studying at the University of York, England. At the beginning of the experiment participants were asked to rate on a 7-point scale their comprehension and production abilities in English (1 = very low, 7 = same as in Spanish). Participants obtained a mean comprehension rating of 5.30 (range 3-6) and a mean production rating of 4.83 (range 4-6).

6.2.2.2 *Materials*

A total of 128 word pairs were created. Each word pair consisted of a Spanish word (L1) and an English word (L2). Sixty-four word pairs formed the critical experimental stimuli and all of them were translation equivalents. The remaining 64 pairs of words were non-translations. The AoA of L1 and the AoA of L2 in the translation sets were orthogonally manipulated creating 4 sets that varied in AoA in the following way: in one set the English and Spanish words were both early acquired. In a second set the English word was acquired early and the Spanish word was late acquired. The English word was late acquired and the Spanish word was early acquired in a third set and in the fourth set the English and Spanish words were both late acquired. A list of the four groups of word pairs can be seen in Appendix 9.

The four sets of word pairs were matched on two English word frequency counts (Celex Lexical Database: Baayen et al., 1993; Kucera & Francis, 1967), Spanish word frequency (Alameda & Cuetos, 1995), English and Spanish letter length, imageability of the English words (from Morrison et al., 1997), imageability of the Spanish words (from Izura & Ellis, 2002) and on translation accuracy. None of the word pairs used were cognates (similar in form and meaning across languages).

Translation accuracy ratings were obtained prior to the completion of Experiment 10. An independent group of 20 dominant Spanish-English bilinguals (9 females, 11 males) with a mean age of 29 years (range 23-46 years) were asked to rate on a 5-point scale the degree of meaning similarity that 399 pair of words shared (1= same meaning, 5= totally different meaning). These raters also rated their comprehension and production skills in English as a second language. Their mean comprehension ratings was 5.25 (range 4-7) and their mean production ratings was 4.85 (range 3-6).

Spanish AoA values were obtained from Cuetos et al. (1999). Early acquired words in Spanish were words that had a rating of less than 4.26, while late acquired words were words that had an AoA rating of more than 4.3 on a 11-point scale where 1 = before 2 years old, to 11 = eleven years old or older. AoA values for English as a second language were obtained from Izura and Ellis (2002). The early acquired words in English as a second language had a rating of less than 2.32 (27.8 months), while the late acquired words in English as a second language had a rating of more than 2.37 (28.40 months). The values for the 4 sets of words on the different variables are shown in Table 6.1.

	Imag. L2	AOA (English) L2	Log K&F L2	Log Celex L2	No letters L2	Imag. L1	AOA (Spanish) L1	Log A&C L1	No. Letters L1	Trans. Acc
Early (L2)										
Early (L1)										
M	5.58	20.02	1.24	1.43	5.63	6.36	3.54	1.47	5.94	1.08
S	1.50	4.52	0.58	0.50	1.67	1.13	0.54	0.61	1.57	0.11
Minimum	1.85	13.20	0.00	0.60	3.00	2.65	2.45	0.48	4.00	1.00
Maximum	6.70	27.00	2.10	2.18	9.00	6.96	4.20	2.50	10.00	1.30
Early (L2)										
Late (L1)										
M	5.49	22.44	1.26	1.40	5.63	6.32	5.06	1.31	6.31	1.09
S	1.36	3.69	0.71	0.52	1.50	0.95	0.97	0.54	1.70	0.13
Minimum	2.85	16.20	0.00	0.60	3.00	3.96	4.30	0.30	4.00	1.00
Maximum	6.90	27.79	2.54	2.29	9.00	6.96	7.65	2.25	10.00	1.45
Late (L2)										
Early (L1)										
M	5.57	42.12	1.17	1.28	5.44	6.23	3.63	1.48	6.00	1.22
S	1.30	9.85	0.46	0.32	1.67	0.82	0.49	0.40	1.75	0.21
Minimum	2.85	28.42	0.30	0.95	3.00	4.87	2.80	0.93	3.00	1.00
Maximum	6.90	64.67	2.11	2.23	10.00	6.91	4.26	2.25	10.00	1.70
Late (L2)										
Late (L1)										
M	5.46	40.58	1.28	1.32	5.44	6.25	5.31	1.41	6.13	1.11
S	1.42	7.92	0.68	0.66	1.71	0.99	0.74	0.53	1.20	0.12
Minimum	2.60	29.40	0.00	0.00	3.00	4.43	4.40	0.78	5.00	1.00
Maximum	6.95	54.32	2.11	2.12	8.00	6.96	7.05	2.58	8.00	1.40

Table 6.1 Mean (M), standard deviation (S) and maximum (Max) and minimum (Min) values for the variables controlled in Experiment 10. Note: AoA = age of acquisition, K&F = Kucera & Francis (1967), Imag = imageability, A&C = Alameda & Cuetos (1995), No Letters = number of letters, Trans Acc = translation accuracy.

Sixty-four non-translation pairs were created. None of the translation words or their equivalents was repeated in the list of non-translations. Like the translation pairs, the non-translations pairs also consist of four groups that varied in their AoA values. The non-translation words covered the same range of imageabilities, frequencies, and lengths as the translation equivalent pairs and there were no significant differences between the translation and non-translation word sets on any of those measures in either Spanish or English.

6.2.2.3 *Procedure*

The word pairs appeared simultaneously in the middle of the screen one above the other. The English word (L2) was presented above the Spanish word (L1) in half of the trials, and below the Spanish word in the other half. Instructions informed the participants that pair of words (one in English and one in Spanish) would appear on the middle of the screen and that their task was to decide as quickly and as accurately as possible if the two words shared the same meaning or not. Participants were also warned that the same block of word pairs would be repeated four times and that only in the first block of trials they would receive feedback.

The experiment was carried out using a Macintosh Centris 660-AV computer. Participants sat facing the screen at a comfortable reading distance. The stimuli were presented on the computer screen in lower case 48 point New York font. Each trial began with a fixation dot of 1000ms duration. The fixation dot was followed by a stimulus pair, which remained on the screen until a response was made. The screen then went blank for 500ms before the next trial began. Participants pressed a red key in a two-choice keypad when they considered that the two words presented on the screen meant the same thing (i.e., were translation equivalents) and a green key if they thought that they did not share the same meaning.

The experiment began with 30 practice trials (15 translations, 15 non-translation pairs involving different filler items). Presentation of items and recording of reaction times was done using the SuperLab experiment generator package (Abboud, 1991).

6.2.3 Results

Only correct responses that fell within 3.5 standard deviations of the mean were analysed. Thirteen (1.01%) fell outside 3.5 standard deviations and were removed from reaction times analyses. Fifty-one responses (3.98%) out of a total of 1280 were errors that involved pressing the wrong key. These were removed from the analysis of RTs.

Mean reaction times, standard deviations, number, and percentage of errors for each condition are shown in Table 6.2.

	Early (L2) Early (L1)	Early (L2) Late (L1)	Late (L2) Early (L1)	Late (L2) Late (L1)
M	862	897	949	930
S	149	139	171	156
Error (%)	2.50	1.56	6.57	5.00

Table 6.2 Mean RTs in milliseconds (M), standard deviations (S) and percent errors (%) in translation judgement in Experiment 10.

6.2.3.1 *Reaction time analysis*

An analysis of variance (2x2) was carried out on the RTs to translation pairs with first language AoA and second language AoA as factors. The main effect of second language AoA was significant, $F_1(1,19) = 27.97$, $MSE = 26040.88$, $p < 0.001$; $F_2(1,15) = 8.54$, $MSE = 58228.71$, $p < 0.05$, with word pairs containing early acquired words in L2 being judged as translation equivalents faster than word pairs containing late acquired words in L2. The main effect of first language AoA was not significant.

The interaction between first and second language AoA was significant, though only in the by-subjects analysis, $F_1(1,19) = 5.60$, $MSE = 2615.13$ $p < 0.05$; $F_2(1,15) = 2.48$, $MSE = 12459.30$, $p > 0.1$. Early acquired words in L1 were judged as translation equivalents faster than late acquired words in L1 only when they were paired with early acquired words in L2. The form of this interaction can be seen in Figure 6.1. T-tests showed a significant difference between early and late acquired words in L1 when paired with early acquired words in L2, $t(19) = -2.17$, $p <0.05$, but not when paired with late acquired words in L2, $t(19) = 0.93$, $p > 0.1$.

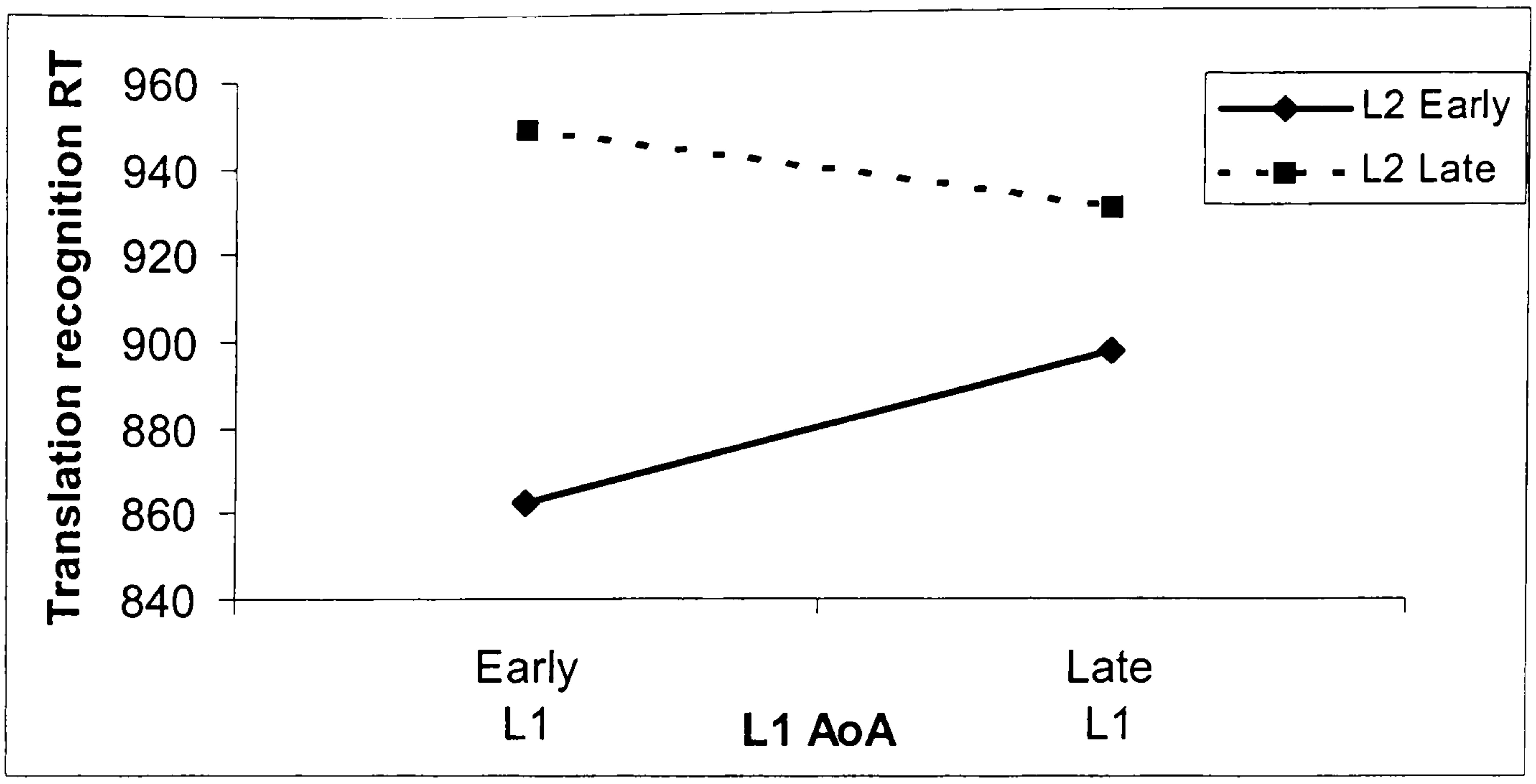


Figure 6.1 Interaction between L1 AoA and L2 AoA in Experiment 10

6.2.3.2 *Error analysis*

The low number of errors precluded the use of the analysis of variance. The repeated measures design, amongst other things, also prevented the use of the non-parametric chi-square (crosstabulation). Instead errors were analysed with a multilevel modelling technique consisting of two levels; level 1 = participants and level 2 = items (see Miles & Shevlin, 2001). The test chosen to apply this technique was the logistic regression analysis. Logistic regression is the test of choice when the dependent variable is dichotomous (0 = correct, 1 = error) since dichotomous variables violate the assumption of normal distribution required in linear multiple regression analysis. The procedure was as follows: Variables were entered hierarchically in the regression. Subjects were represented in the model as independent variables. As 20 subjects completed the experiment, 20 'subject variables' were entered in the first block of the logistic regression. L1

AoA, L2 AoA, imageability, L1 and L2 word length, and L1 and L2 word frequency were entered in the second block of the hierarchical analysis along with repetition as a categorical variable, to assess their influence on number of errors once the variance associated with the subjects has been accounted for.

The overall chi-square for the model was significant, $\chi^2(31) = 184.02$, $p < 0.001$. In the analysis including all variables only L2 AoA significantly predicted number of errors ($p < 0.001$). Overall, fewer errors were made to the word pairs containing early acquired words in L2 (2.03%) than to the pairs containing late acquired words in L2 (5.93%).

6.2.4 Discussion

A main effect of AoA on translation judgement RTs was found for English as a second language. Participants decided more quickly that pair of words were translations if the L2 word in the pair was early acquired in L2 than if it was late acquired. This is the first demonstration of a second language AoA effect in a translation task. L1 and L2 AoA interacted, suggesting that first language AoA also has an impact in translation recognition. First language AoA influenced translation judgement speed when the Spanish (L1) word was paired with a word that was early acquired in L2 (English). When Spanish words were paired with words that were late acquired in English as a second language there was no effect of Spanish AoA.

A translation judgement task requires the recognition of two words - one in L1; one in L2. It is conceivable that the simultaneous presentation of the two words led to a parallel activation of both of them. It could be argued that late acquired words in L2 (English) took so long to be recognised that by the time this process was accomplished its early or late acquired translation in L1 had already been processed. As a consequence, first language AoA effect was diminished and lost in those trials in which a L1 word was paired with a late acquired L2 word. Experiments 11 and 12 attempted to test this possible explanation of why L1 AoA only affected RTs in Experiment 10 when the English word was early acquired in L2.

6.3 Experiment 11 – AoA effects on a lexical decision task

6.3.1 Introduction

In Experiment 11 the AoA effect in L1 (Spanish) and L2 (English) was explored in a lexical decision task using the same stimuli as in Experiment 10. It was thought that the AoA effect of the L1 words used in Experiment 10 may have been masked by the slow processing of late acquired words in L2. To determine whether this is a plausible explanation, recognition speeds for the L1 and L2 words were examined. Experiment 11 consisted of two lexical decision tasks, one in Spanish (L1), and one in English (L2), using the same experimental stimuli as Experiment 10.

6.3.2 Method

6.3.2.1 *Participants*

Two groups, A and B, of twenty dominant Spanish-English bilinguals each completed a lexical decision in Spanish (15 females, 5 males) and a lexical decision in English (15 females, 5 males) respectively. Group A had a mean age of 27 years (range 18-38 years). The mean age of group B was also 27 years (range 21 –35). At the time of testing participants of group A and B had been living in England for a mean time of 2 years with a range of 3months - 8 years for group A and of 1month- 7 years for group B. Group A started to be instructed in English at a mean age of 13 years (range 8-29 years) and group B at 11 years of age (range 8-14). Participants in group A had been learning English as a second language for an average of 11 years (range 4-23years) while participants of group B had an average of 12 years (range 6-23). The participants' mean comprehension ratings for English were 5.60 (range 4-7) in group A and 5.10 (range 4-7) in group B. The participants' mean production ratings for English were 5.30 (range 4-7) in group A and 5.00 (range 4-7) in group B[1].

[1] Bilinguals who are able to speak their two languages with a native-like proficiency are rare. It is more common to find bilinguals who are more fluent in one language (normally the mother tongue) than the other. Change of language dominance in bilinguals can occur when a variable number of language circumstances are altered such as language contact, frequency of use, social pressures, etc. Assessing language proficiency is a difficult task. The groups of bilinguals that completed the experiments in this study provided a self-rated assessment for their proficiency in comprehension and production in English, their L2. Three participants (two in Experiment 11 and one in Experiment 12) rated themselves as having in English equal proficiency as in Spanish. This could suggest a change of language dominance in these bilinguals. A closer look at the self assessment of these three participants revealed that they had been living in England for only one year and started to learn English at the age of 11 or 12 years of age. Like other methods of assessing language proficiency, self-ratings are not ideal. It is difficult to tell why these bilinguals rated themselves equally proficient in both languages but it is my intuition that even for these participants the dominant language was still the first language, Spanish.

A series of t-tests were conducted to assess if group A and B differed in any of the characteristics mentioned. No significant differences were found regarding their age, the time spent in England, the time at which they started to learn English, the time spent learning English and their rated production abilities in English. A significant difference was found, however, regarding their rated comprehension skills, $t(19) = -2.12$, $p<0.05$, with better rated comprehension in group B than in group A.

6.3.2.2 *Materials*

The stimuli consisted of 128 words (64 English words that were the translation equivalents of the remaining 64 Spanish words) and 128 nonwords. The words were the same used in the translation pairs of Experiment 10. Sixty-four nonwords were created from real Spanish words by changing one letter in such way that they remained orthographically legal in Spanish and in a similar way 64 nonwords were created from real English words.

6.3.2.3 *Procedure*

The two parts of the experiment consisted of a lexical decision task in English and a lexical decision task in Spanish. Twenty participants completed the lexical decision task in Spanish and the other 20 the lexical decision task in English. At the start of the experiment 20 practice trials were presented (10 words and 10 nonwords).

Presentation of items and recording of reaction times was done using SuperLab experiment generator package (Abboud, 1991). The experiment was carried out using a Macintosh Centris 660-AV computer. Participants sat facing the screen at a comfortable reading distance. The stimuli were presented on the computer screen in lower case 48 point New York font. In both tasks each trial began with a fixation dot of 1000ms duration followed by a stimulus word or nonword which remained on the screen until a response was made. The screen then went blank for 250ms before the next trial began. Participants pressed the B key on a standard Qwerty keyboard if the item was a word and the N key if it was a nonword.

6.3.3 Results

Only correct responses that fell within 3.5 standard deviations of the mean for that language were analysed. Twenty responses (1.56%) to Spanish words and sixteen responses (1.25%) to English words fell outside 3.5 SDs and were removed from further analysis. Ninety-five responses (1.85%) out of a total of 5120 were errors that involved pressing the wrong key and were removed from further analyses.

Mean reaction times, standard deviations, number, and percentage of errors for each condition are shown in Table 6.3.

	L1 (Spanish)		L2 (English)	
	Early	Late	Early	Late
M	632	661	706	760
S	103	123	131	123
Error (%)	0.78	1.09	1.25	4.30

Table 6.3 Mean (M), standard deviation (S) and percent error (% error) in Experiment 11

6.3.3.1 *Reaction time analysis*

An analysis of variance was carried out on the reaction times to real words, with AoA and language as factors. A main effect of AoA was found, $F_1(1,38) = 34.99$, $MSE = 34499.80$, $p < 0.001$; $F_2(1,128) = 11.88$, $MSE = 62583.24$, $p < 0.05$, with early acquired words being recognised faster than late acquired words. There was also a main effect of language, $F_1(1,38) = 5.20$, $MSE = 147823.70$, $p < 0.05$; $F_2(1,128) = 58.10$, $MSE = 306183.45$, $p < 0.001$, with decision latencies being faster for L1 than for L2. The interaction between language and AoA was not significant.

The mean reaction times for correctly rejecting nonwords in the Spanish and English conditions were 842 ms and 969 ms respectively. The difference in reaction times was significant, $t_1(19) = -2.98$, $p < 0.05$; $t_2(63) = -6.06$, $p < 0.001$. Participants took longer to reject nonwords in English than in Spanish.

6.3.3.2 *Error analysis*

Analysis of the error rates using the Wilcoxon matched-pairs signed ranks test revealed a significantly higher rates of errors to early than to late acquired words in L2 (English), $Z = -3.36$, $p < 0.05$, but no significant difference was found for L1 (Spanish), $Z = -.92$, $p > 0.1$.

6.3.4 Discussion

The results of Experiment 11 showed that English lexical decision latencies were affected by AoA in English as a second language. It was also observed that first language AoA affected Spanish (L1) lexical decision performance. In general, participants took longer to reject nonwords than to accept real words, and the rejection time was significantly longer for nonwords based on English words than for nonwords based in Spanish words.

The AoA effect found for Spanish (L1) is of special interest. In Experiment 11 participants recognised letter strings as words in L1 quicker if they were early acquired than if they were acquired later. Since the same words were used in Experiment 10 and 11 there is some reason to think that in Experiment 10 early acquired words in L1 were also recognised faster than late acquired words in L1. However, first language AoA did not show a significant effect in Experiment 10. It is argued that the first language AoA effect was overshadowed in Experiment 10. The recognition and comprehension of words is more difficult in the non-dominant, second language than in the dominant, first language. This added difficulty encountered in L2 word processing is reflected in increased word recognition latencies for L2 words and this extra time devoted to L2 word recognition was the cause of masking the AoA influence over L1 words. One indication that this might be the case is the language effect, with larger decision latencies for L2 than for L1, and the amount of overlap between the different groups of words. As Figure 6.2 shows, there was substantially more overlap in RT between early acquired words in L2 and any word in L1 than between late acquired words in L2 and L1 words. This might be an indication of similar speed of access to semantics for early acquired words in L2 and L1 words, supporting the hypothesis that in Experiment 10 only early acquired words in L2 accessed the semantic representations quickly enough to allow differences between early and late acquired words in L1 to emerge.

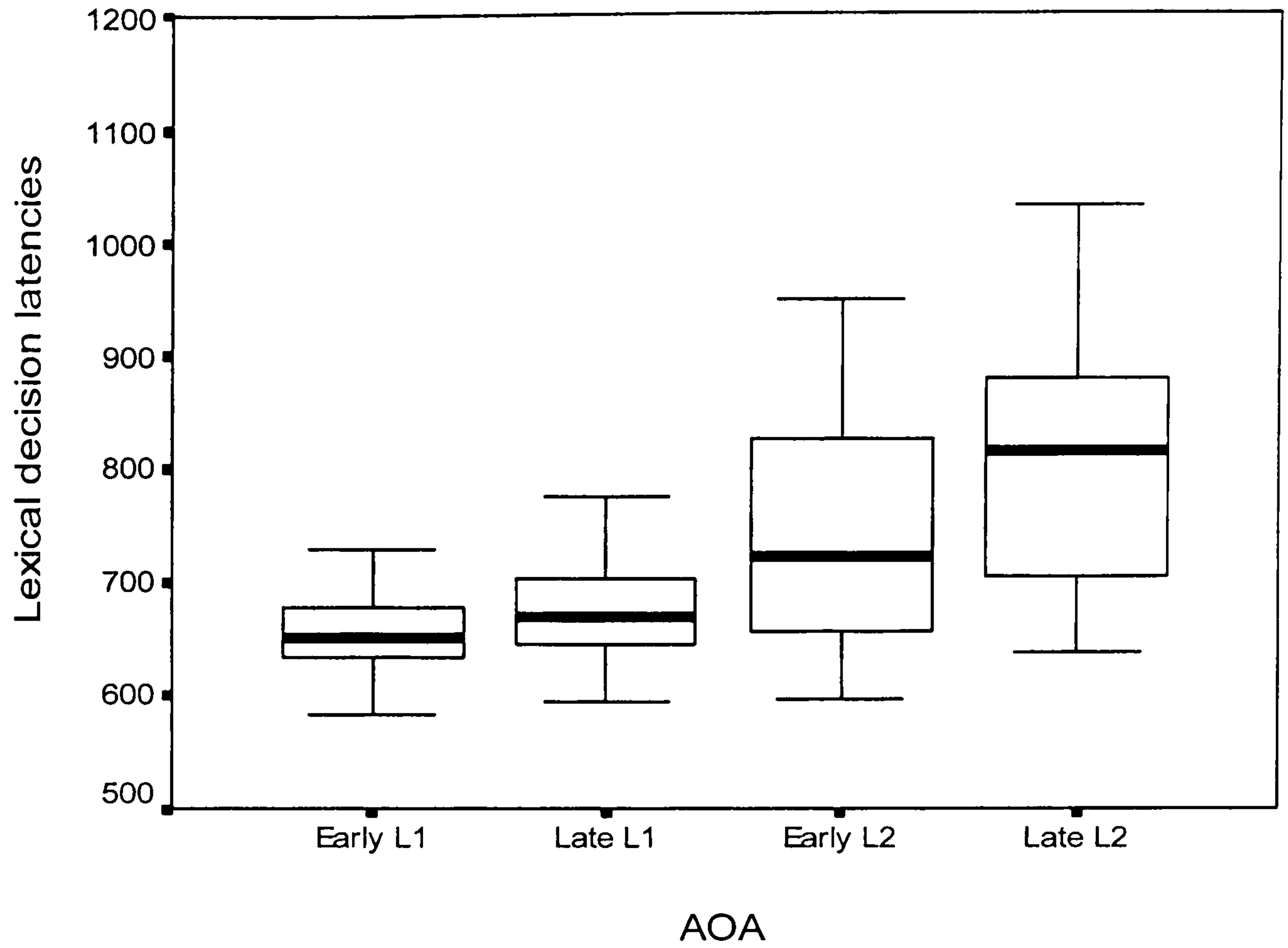


Figure 6.2 Boxplot of the decision latencies for early and late acquired words in L1 and L2 (Experiment 11). Early acquired words in L2 show more overlap with words in L1 (early or late) than late acquired words.

6.4 Experiment 12 – AoA effects on a sequential translation judgement task

6.4.1 Introduction

Experiment 12 returned to the translation recognition task as a means of observing first and second language AoA effects. Following the argument derived from Experiment 11 that word recognition latencies for late acquired words in L2 could have disguised a first language AoA effect for the L1 words paired with them, a sequential rather than a simultaneous translation recognition task was created. This time participants had to decide if an L1 word was the translation equivalent of an L2 word presented 400ms earlier. It was thought that giving a head start to L2 words would mean more of an overlap between recognition speeds for L1 and L2 words.

6.4.2 Method

6.4.2.1 *Participants*

Twenty dominant Spanish-English bilinguals (9 females, 11 males) with a mean age of 27 years (range 19-25 years) completed the experiment. At the time of testing participants had been living in England for a mean time of 2 years (range 1 month-5 years). Their first contact with English was at a mean age of 12 years (range 8-26 years) and they had been learning English as a second language for an average of 9 years (range 4-15 years). Participants provided a mean comprehension rating of 5.30 (range 4-6) and a mean production rating of 5.00 (range 4-7).

6.4.2.2 *Materials*

The stimuli used in Experiment 12 were the same used in Experiment 10, 64 word pairs that were translation equivalents and 64 word pairs that were non-translations. The translation equivalents varied on first and second language AoA.

6.4.2.3 *Procedure*

The English word was presented first and in isolation for 400ms. The word in Spanish then appeared below the English word with the word pair centred in the middle of the computer screen. Participants were asked to decide as quickly and as accurately as possible if the Spanish word (L1) had the same meaning as the English word (L2).

The experiment was carried out using a Macintosh Centris 660-AV computer. Participants sat facing the screen at a comfortable reading distance. The stimuli were presented on the computer screen in lower case 48 point New York font. Each trial began with a fixation dot of 1000ms duration followed by an English word that remained on the screen for 400ms. Then, a Spanish word appeared one line below the English word and the stimulus pair remained on the screen until a response was made. The screen then went blank for 500ms before the next trial began. Participants pressed a red key on a two-choice keypad if the two words meant the same and a green key if the two words had different meanings.

The experiment began with 30 practice trials (15 translations, 15 non-translation pairs). Presentation of items and recording of reaction times was done using SuperLab experiment generator package (Abboud, 1991).

6.4.3 Results

Only correct responses that fell within 3.5 standard deviations of the mean were analysed. Overall twenty-nine responses (2.26%) fell outside 3.5 SDs and were removed from further analysis. Sixty-nine responses (5.39%) out of a total of 1280 were errors that involved pressing the wrong key and were removed from the analysis.

Mean reaction times, standard deviations, number, and percentage of errors for each condition are shown in Table 6.4.

	Early L2 Early L1	Early L2 Late L1	Late L2 Early L1	Late L2 Late L1
M	620	639	660	695
S	152	145	149	151
Error (%)	2.5	2.18	7.18	9.06

Table 6.4 Mean (M), standard deviation (S) and percent error (% error) in Experiment 12 (sequential translation judgement).

6.4.3.1 *Reaction time analysis*

An analysis of variance was carried out with Spanish AoA and English AoA as factors. The main effect of English AoA was significant, $F_1(1,19) = 18.66$, $MSE = 46638.48$, $p < 0.001$; $F_2(1,15) = 11.20$, $MSE = 37200.77$, $p < 0.05$, with word pairs containing early acquired English words being judged faster than word pairs containing late acquired

English words. This time the main effect of Spanish AoA was also significant, $F_1(1,19) = 8.88$, $MSE = 14001.04$, $p < 0.05$; $F_2(1,15) = 5.71$, $MSE = 9875.39$, $p < 0.05$, with word pairs containing early acquired words in Spanish being recognised faster than word pairs containing late acquired words in Spanish. No significant interactions were found.

6.4.3.2 *Error analysis*

As in Experiment 10 the low number of errors and the repeated measures design lead to the use a multilevel modelling technique with two levels: level 1 = participants and level 2 = items. The test chosen was again a logistic regression analysis since our dependent variable was dichotomous (0 = no error, 1 = error). Variables were entered hierarchically into the analysis. Subjects were represented as independent variables therefore 20 'subject variables' were entered in the first block of the hierarchical logistic regression analysis. L1 AoA, L2 AoA, imageability, L1 and L2 word length, and L1 and L2 word frequency were entered in the second block of the hierarchical analysis. The overall chi-square for the model was significant, $\chi^2(28) = 112.71$, $p < 0.001$. In the analysis including all variables, L2 AoA but not L1 AoA emerged as a significant predictor of number of errors ($p < 0.001$). Participants were more accurate at deciding that pairs of words were translation if the L2 word in the pair was early acquired than if it was a late acquired word.

6.4.4 Discussion

In Experiment 12, effects of AoA in both L2 (English) and L1 (Spanish) were found. Whereas in Experiment 10 L1 AoA only affected translation judgements for words paired with early L2 equivalents, in Experiment 12 there was an effect of L1 AoA for words paired with both early and late L2 equivalents. The difference between Experiments 10 and 12 was the fact that Experiment 10 the Spanish (L1) and English (L2) words were presented simultaneously while in Experiment 12 the English words were given a head start on the Spanish words. We suggest that observing an L1 AoA effect for words paired with late acquired L2 items depends on giving the L2 words a processing advantage so that they access semantics at about the same time as the L1 words.

6.5 General Discussion

The results obtained in Chapter Six indicate that AoA exerts a significant influence on some of the process involved in word translation processes such as word comprehension. This is the first indication of an AoA effect in word translation and in word comprehension in L1 and L2.

In Experiment 10, dominant Spanish-English bilinguals completed a simultaneous translation recognition task. The AoA of L2 (English) emerged as significant contributor of translation latencies. The AoA of L1 (Spanish) did not show a main effect but interacted with second language AoA. The interaction indicated that first language AoA effect predominated when participants judged that early or late acquired words in L1 were the translation equivalents of early acquired words in L2 but not when the same decision was made upon late acquired words in L2.

The main finding of a second language AoA effect creates problems for the semantic account of AoA. In L1 the order of acquisition of the meanings and the words that represent them is closely related. Their high mutual dependence produces as a consequence equal AoA values for first language words and their meanings. Once a first language is established, the formation of new meanings is not a requirement in the acquisition of a second language (unless a second language word implies a new concept). Pre-existing meanings will be used to incorporate a brand new vocabulary into the language system of the future bilingual. As most researchers agree (De Bot, 1992; Costa et al., 1999; Hell & de Groot, 1998; Kroll & Stewart, 1994), L1 and L2 share, in general, the same meanings or semantic representations. If the AoA effect rises only from these semantic representations that are endowed with the AoA properties of L1, no second language AoA effect would be expected in a translation task. Experiments 10 and 12 shows that this is clearly not the case. However, two alternative theories of AoA will account for the results of the present study. One locates the AoA effect at the lexical level, the other situates the effect in the connections between representations. Gerhand and Barry (2000) have defended AoA as a property of the lexical representations. As indicated in section 1.7.1.3 (pp. 64), Gerhand and Barry's (2000) study showed that LW, a deep dyslexic patient, read early acquired words with higher accuracy than late acquired words. Furthermore the semantic errors uttered by LW were consistently earlier than the target word. This results lead Gerhand and Barry (2000) to conclude that AoA emerges from an intermediate level between the concept representations and the phonology; the lemmas.

The second account of AoA is based on the performance of a connectionist network. As explained in section 1.7.2 (pp. 66), Ellis and Lambon Ralph (2000) argued that the AoA effect rests on the connections between representations. They observed that a trained network showed better performance for early than for late entered patterns. Ellis and Lambon Ralph (2000) suggested that the loss of plasticity resulting from the training with early entered patterns is the cause of a decrease in the performance of late entered patterns. This was true even when the late entered patterns were trained at a higher frequency than the early items so that cumulative frequency of training was matched. A similar loss in plasticity would cause the formation of more efficient connections for early than for late acquired words explaining the AoA effects in human lexical processing.

The findings of Chapter Four did not support the idea of plasticity loss in human behaviour, however, L1 and L2 AoA effects can still be placed at the connections between representations. Indeed the results of Experiments 10 and 12 are compatible with both the lexical and connection strength accounts of AoA. Separate AoA effects for L1 and for L2 are predicted and expected whether AoA is located at the lexical level or in the links between lexical and semantic representations.

The interaction found in Experiment 10 between first and second language AoA was interpreted as a consequence of different word recognition speed for L1 and L2. A parallel processing of two words (one in L1, one in L2) is initiated by the simultaneous presentation of the pairs. Those words acquired late in L2 are more difficult to recognise. This difficulty is expressed in the extra time required to recognise these words. It could be conceivable to consider that by the time late acquired words in L2 were identified, their translation equivalents were already processed and therefore any differences between early and late acquired words in L1 vanished. However, the access to early acquired words in L2 might be relatively easy to accomplish allowing differences in the AoA of the translations in L1 to emerge.

The results of Experiment 11 and Experiment 12 supported this hypothesis. Experiment 11 showed that dominant Spanish-English bilinguals distinguished real words more quickly if they were early acquired than if they were late acquired. Importantly, this was the case irrespective of the language. First language AoA affected the lexical decision task in L1 and second language AoA affected the lexical decision task in L2. Participants were also significantly faster in the first language than in the second language adding support to the idea of long recognition latencies for L2. In Experiment 12 the translation recognition task was revisited. It was hypothesised that if the slow recognition times of L2 words were truly overshadowing first language AoA effects, an initial advantage to process L2 words would facilitate the observation of the AoA effect for L1. In Experiment 12, L2 words were presented 400ms before L1 words, once the word in L1 had appeared participants decided if the pair shared or did not share the same meaning. Decision times showed that second language AoA and also first language AoA affected translation judgement.

AoA correlates significantly in first languages with both word frequency and imageability (Gilhooly & Logie, 1980; Morrison & Ellis, 1995). That is because early words tend to be more imageable than later words which contain a higher proportion of abstract meanings, and early words tend to be used with higher frequency in adulthood. Experience in the domain of monolingual language processing shows that apparent effects of frequency and imageability are often reduced once AoA is controlled (e.g., Barry et al., 2001; Morrison & Ellis, 1995; Monaghan & Ellis, 2002b; Ellis & Monaghan, 2002; Turner et al., 1998). None of the studies that have reported effects of frequency and imageability on translation speed have controlled AoA (e.g., De Groot, 1992; De Groot & Comijs, 1995; De Groot et al., 1994; De Groot & Poot, 1997; Hell & De Groot, 1998) and suggest that future studies will need to re-examine the reported effects of these variables with AoA controlled to see if they really do exert independent effects on translation speed.

CHAPTER SEVEN

THE AoA EFFECT IN A SECOND LANGUAGE ACQUIRED DURING ADULTHOOD: IMPLICATIONS FOR CURRENT AoA ACCOUNTS

7.1 Introduction and summary of main findings

Since Carroll and White (1973a) reported the first AoA effect on object naming times, a considerable amount of research has been devoted to exploring the AoA effect. Evidence has been gathered supporting the claim that words acquired at an early stage are recognised and named faster than words acquired some time later. The AoA effect found in tasks such as face recognition is an indication that the effect might not only be lexical and consequently that the influence of AoA extends to other processes. Given the largely demonstrated cognitive impact of AoA a number of accounts (Brown & Watson, 1987; Gilhooly & Watson, 1981) have been formulated as attempts to explain the locus and underlying mechanisms of the effect. Particularly noteworthy are the current implementations of the AoA effect in connectionist networks (Ellis & Lambon Ralph, 2000; Steyvers & Tenenbaum, 2002; Zevin & Seidenberg, 2002) that have introduced new interpretations of the effect while opening a new line of research.

The extensive research conducted on AoA has served to bestow upon the AoA effect a previously ignored status as a powerful determinant of processing speed. However, there are still unresolved questions regarding the nature and location of the effect. In this thesis the AoA effect was examined in the first and second languages of dominant bilinguals to identify constraints on the character and location of the AoA effect.

Chapter Two consisted of two pilot experiments in which an AoA effect was observed when English and Spanish native speakers distinguished words from nonwords in their mother tongue. The English AoA effect found in Experiment 1 supports similar findings reported in the literature (Butler & Hains, 1979; Cirrin, 1984; Morrison & Ellis, 1995; Turner et al., 1998). The results of Experiment 2 gave the first demonstration of an AoA effect in word recognition in Spanish language. This finding further strengthens claims of AoA effects in Spanish as shown in Cuetos et al.'s (1999) picture naming study. The Spanish AoA effect found in Experiment 2 supports the idea, also implicit in other studies with foreign languages (Kremin et al., 2000; Bates et al., 2001; Yamazaki et al., 1997), of AoA as an universal word attribute not only restricted to the English language.

Chapter Three sought to test the hypothesis of AoA effects being the result of a maturationally delimited critical period. If AoA is an age-related effect, processing speed differences between early and late acquired words could be linked to the decline of language learning capacity. If this is so, no AoA effects would be found in a language acquired after early childhood.

Ratings for AoA of English as a second language were collected. Using these ratings and the reported AoA values for Spanish as L1 by Cuetos et al. (1999), Experiment 3 indicated that bilinguals show a significant influence of AoA in L1 and L2 when naming pictures. The use of the same pictures to be named in L1 and L2 caused an interference effect across languages. The interference was larger for L1 than for L2. This effect was interpreted following the principles of the inhibitory control model, IC (Green, 1998), discussed in Chapter One. A control mechanism inhibits the L1 word when naming in L2. The reactivation of the previously inhibited word in the second phase of Experiment 3 created an unexpected competition effect delaying reaction times in L1 especially but also retarding naming times of early acquired words in L2. Experiment 4, a lexical decision task, was designed with words that were not translation equivalents of one another to avoid cross languages interference. An AoA effect for English as L2 and for Spanish as L1 was found.

The results of Experiments 3 and 4 suggested that order of word acquisition and not the age of vocabulary learning was responsible for the AoA effect. However, both experiments consisted of stimuli whose names had been early or late acquired in both languages. This detail becomes crucial if AoA is conceived as a property of the semantic representations. The reason for this is that assuming that the semantic system is shared between the two languages of a bilingual, L1 AoA would be the only cause of differences in the speed of word processing in L1 and L2 since meanings are acquired only once at the time of learning the first language. This possibility left the question of AoA and its relation with critical periods or maturational constraints unresolved and therefore it was further investigated in Experiments 5 and 6 in Chapter Four.

Experiments 5 and 6 sought to test a possible interdependence between L1 and L2 AoA effects. Two lexical decision tasks were designed: one to be analysed using multiple regression (Experiment 5), the other manipulated L1 and L2 AoA orthogonally in a factorial design (Experiment 6). In Experiment 5, L2 AoA accounted for a significant percentage of unique variance on lexical decision times to L2 while L1 AoA did not predict at all reaction times to recognise L2 words. Experiment 6 supported this finding showing that word recognition times in L2 were affected by L2 AoA independently of the AoA value that the translation equivalent had in L1. Similarly, L1 AoA influenced only the speed at which words in L1 were recognised. The AoA effect for English as a second language was found in a number of experiments throughout the Thesis (Experiments 3, 4, 7, 8, 10, 11 and 12), thereby providing an indication of the reliability of this effect.

Another finding derived from the results of Experiments 5 and 6 was larger AoA effects for English as L2 than for Spanish as L1. The greater influence of AoA on L2 than on L1 was explained as the result of L2 representing a language not completely acquired. L2 words in general, but essentially late acquired L2 words, should hold the least robust and the most unstable representations. This stage of vocabulary acquisition where some words in the second language are not fully specified had an impact on lexical performance causing larger AoA effects in L2 than in the well acquired L1.

Chapter Four concluded that the influence of AoA on L2 learnt after childhood indicates that the origins of the effect are not the result of learning early words during a period of time where the ability for language acquisition is maximised and late words acquired some time after this period. The AoA effect therefore is not limited by maturational constraints. This finding questions the applicability of Ellis and Lambon Ralph (2000) suggestion of the mechanisms underlying the AoA effect. The argued loss of plasticity of the network by the time late patterns were entered into the model does not seem to correlate with human performance.

The results of Experiments 5 and 6 also indicated an independent relation between L1 AoA and L2 AoA. L2 AoA values are not the same as L1 AoA values inherited through the bilingual shared semantic system. Order of word learning in L2 and L1 is similar for a fraction of the second language vocabulary. However, there is a proportion of words learnt in different orders in the two languages when the learner is exposed to L2 during adulthood. The different acquisition orders are not transferable across languages (through an assumed shared semantic system) and this fact turns L2 AoA into an influential factor in L2 lexical processing. The independent contribution of L2 AoA to cognitive processes in L2 also suggests that the AoA is a lexical rather than a semantic effect.

Chapter Five then set out to investigate a recent lexical account of the AoA effect (Ellis & Lambon Ralph, 2000). Ellis and Lambon Ralph (2000) claimed firstly that AoA influences the effectiveness with which connections between representations (e.g., meaning and word form) are established. According to Ellis and Lambon Ralph (2000), early acquired words enjoy more efficient connections than late acquired words. Secondly, AoA effects are regulated by the arbitrary/predictable nature of the established connections. Arbitrary connections are more prone to show AoA effects than predictable connections. This is so because early and arbitrary connections (e.g., the association created between the concept of doll and the word form *doll*) are not useful to create late arbitrary connections (e.g., between the concept of dollar and the word form *dollar*). However, early predictable connections (e.g., orthographic form *doll* and phonological form */dol/*) can be exploited when late predictable connections are created (e.g., the early connection between *doll* and */dol/* might be useful to connect at least part of the orthography and phonology of *dollar* and */dolar/*).

This hypothesis of AoA emerging from the nature of the connections between representations was tested by completing a comparison between the word reading times of Spanish-English bilinguals in their two languages. The size of the AoA effect in the participants' two languages was also assessed in relation to the word naming latencies of English native speakers.

This comparison found larger AoA effects in English as a first and second language than in Spanish. Taking into account that in terms of spelling-sound correspondences English is a more unpredictable language than Spanish, the findings were consistent with Ellis and Lambon Ralph's (2000) account that predicts larger AoA effects when connections are arbitrarily established than when connections are predictable. However, these results are difficult to accommodate with the proposed semantic location for the AoA effect (Brysbaert, Lange et al., 2000; Colombo & Burani, 2002). If the AoA effect was emerging from the semantic representations and these are consulted when reading in regular languages, equally large differences between early and late acquired words would be expected irrespective of the language (English or Spanish) in use.

The final study of this thesis investigated L1 and L2 AoA effects in translation recognition tasks. The task that was selected was a semantic task in which the proposed semantic nature of AoA (Byrsbaert, Van Wijnendaele et al., 2000) could be explored. In addition, translation recognition offered the opportunity to explore the AoA influence on a word comprehension task. L1 and L2 AoA affected translation recognition times when an L2 word was presented 400ms before the presentation of the L1 word, Experiment 11. The simultaneous presentation of the two words (one in L1, one in L2) produced AoA effects of L2 only (Experiment 9). This result was interpreted as the slow processing of L2 words especially for late acquired L2 words. The pace of processing in L2 overshadowed the effect of AoA in L1.

The fact that L1 and L2 AoA affected the translation recognition times in Experiment 11 where L1 and L2 AoA were orthogonally manipulated suggests once again that AoA is not located at the semantic level but at a lexical level either situated at the connections between representations or at the lemma level.

One of the predictions derived from Ellis and Lambon Ralph's (2000) AoA account is that AoA would affect not only word production and word recognition processing speed but also word comprehension. This prediction was supported by the results of Experiments 9 and 11 where AoA effects were found in a translation recognition task in which the comprehension of L1 and L2 words is required.

Finally, Chapter Six showed AoA effects in a bilingual task often used as a tool to disentangle diverse aspects of the bilingual lexical organisation. Few studies have been concerned with which type of word attributes have an influence on these type of tasks and the existing studies have completely ignored the potential effect of AoA of the first and second language.

Overall, the experiments in this thesis have provided strong evidence for the influence of L2 AoA on L2 lexical processing, the independence of L2 AoA from L1 AoA when L2 has been acquired after early childhood and the non-semantic origin of the AoA effect. The implications of these results for current theories of AoA and for bilingual and monolingual models of word processing are discussed below.

7.2 Critical Period and the AoA effect

The term critical period for language acquisition refers to an interval of time during development where learning a language must take place in order to achieve a high degree of success. The notion of a critical period for first language acquisition is generally accepted amongst researchers but controversy arises when the critical period claim is extended to second language learning. Diverse biological aspects changing with maturation such as hemispheric lateralization or mylenitation processes have been explored as potential factors responsible for a critical period for language learning. However, the results are inconclusive and controversial. From a psychological point of view it is considered that a critical period for the acquisition of all linguistic aspects of second language learning is too simplistic. Therefore researchers favour the idea of several critical periods for different linguistic features.

Just as critical periods have been detected for the ultimate attainment of second language phonology, morphology and syntax, vocabulary learning has not been shown to be affected by maturational constraints (Markson & Bloom, 1997). The notion of vocabulary learning being free from maturational constraints supports the finding of an L2 AoA effect independent of the L1 AoA effect. If a critical period existed for vocabulary learning L1 AoA effects could easily be explained with the argument of early words showing a processing advantage over late acquired words because the former are learnt during a critical period of vocabulary acquisition. However, the critical period hypothesis does not explain the L2 AoA effects found in this thesis for experimental participants who become bilinguals late in life.

The L2 AoA effect found through the experiments of this thesis contradicts Ellis and Lambon Ralph's (2000) suggestion of AoA effects being due to loss of plasticity. Ellis and Lambon Ralph's (2000) successful implementation of the AoA effect in a network lead them to suggest that: "AoA effects should occur whenever learning is cumulative and accompanied by a gradual decline in the plasticity of the network responsible for learning patterns and associations"(pp. 1121). While it is possible that effects of AoA might be found in situations of cumulative learning the results of this thesis did not find a human correlate for AoA being due to plasticity decline. On the contrary, the present thesis provides strong support for the AoA effect being due to the order of word acquisition rather than the actual age at which words are acquired.

7.3 The semantic representations in bilinguals and the AoA effect

A crucial matter of research in bilingualism has been the question of how the two languages are represented in the minds of bilingual speakers. There are a number of proposals about the nature of the bilingual lexico-semantic system (Dijkstra, Van Jaarsveld, & Ten Brinke 1998; Green, 1998; Kroll & Stewart, 1994; Potter et al., 1984) most of which assume a common semantic storage for the meanings of words across languages. This hypothesis of common conceptual representations has been supported by the outcomes of a variety of lexical tasks. Thus, using the cross-language priming task priming effects have been found from semantically related primes to target words in the bilingual's other language (Chen & Ng, 1989; De Groot & Nas, 1991). In the bilingual version of the picture-word interference task (Costa et al., 1999; Hermans, Bongaerts, De Bot, & Schreuder, 1998) reliable cross language interference effects have been found when distractors in one language are semantically related to words to be spoken in the other language. If words in the two languages accessed different semantic representations, then under the conditions of speeded timing in these tasks, we should not expect to see cross-language priming or language interference on these tasks. The fact that it is obtained under these conditions suggests that the semantic representation that is accessed is common to both languages.

However, De Groot (1992) proposed an alternative to the shared semantic hypothesis based on the idea of distributed representations for concepts as opposed to local representations of concepts. In De Groot's (1992) distributed feature model, concepts are represented in a distributive manner as sets of semantic features. Translation equivalents across languages share more or less semantic units depending on the type of word being represented. Thus, concrete words are assumed to hold higher semantic overlap than abstract words and similarly cognates share more semantic features than noncognates. Importantly, the degree of semantic overlap across translation equivalents does not imply that meanings across languages differ completely but that translations might have slightly different units of semantic features.

The present thesis has demonstrated that L2 AoA influences lexical processing in L2 irrespective of the AoA values that translation equivalents have in L1. This result lead to the suggestion of AoA being located at the lexical level or the connections between representations since both accounts predict independent AoA effects for the first and second language. It was thought that if AoA effects emerge from a semantic system shared across both languages, no L2 AoA effect would have been found since the meaning of words would inherit the L1 AoA values only.

7.4 Conclusions

The present thesis has shown that L1 AoA and importantly L2 AoA influence performance in a number of lexical tasks. Words acquired earlier in life or first in the adult acquisition of a second language are processed faster than late acquired words in picture naming, word reading, lexical decision and translation recognition tasks. These findings show that the AoA effect is due to the order of vocabulary learning and this constitutes an integral part of the lexical system of each of the languages of a bilingual. It has been demonstrated that L1 AoA and L2 AoA effects are independent suggesting a lexical (lemmas or connections between representations) rather than a semantic nature for the AoA effect.

The results of the experiments of the present thesis also indicate that the degree of the AoA influence depends upon the task and language in use. Larger effects were found in object naming, lexical decision and translation recognition than in word reading. In addition, word reading in English, with a relatively irregular orthography, shows larger AoA effects than word reading in Spanish, with a highly regular orthography. These differences in the size of the AoA effect support Ellis and Lambon Ralph's (2000) account of AoA that predicts AoA effects whenever arbitrary connections between representations (e.g., naming pictures in any language) are established. However, when the connections are not arbitrary but predictable (e.g., naming words in Spanish), Ellis and Lambon Ralph's (2000) account predicts reduced AoA effects.

On the basis of the results of the present thesis, it is concluded that models of bilingual and monolingual word processing should start to take the AoA effect into account and attempt to explain it as a crucial property of the language system.

7.5 Future directions

7.5.1 Modelling the AoA effect in current models of bilingual and monolingual lexical processing

Despite the large amount of evidence of AoA effects on a number of lexical tasks, monolingual and bilingual models of language processing have failed to account for the AoA effects. The reading models discussed in the Introduction (DRC and PDP models) have been successively improved through modifications that have progressively incorporated into the models new aspects of normal and impaired word reading (e.g., nonword reading, consistency effects, frequency effects, phonological and surface dyslexia, etc).

The DRC model postulates two routes for word reading, a lexical route with stored representations of the pronunciation of the word, and a nonlexical route, where grapheme-phoneme correspondences are encoded in the form of rules. The interaction between word frequency and consistency found in normal word reading is accounted by the DRC model as a competition created between the outcomes of the lexical and nonlexical route for low frequency words. Reading high frequency words does not create competition because the lexical processing of high frequency words is complete before the non-lexical route reaches total activation.

The key feature of PDP models is that they have a single procedure for computing a phonological representation onto a orthographic representation and this procedure is applicable to nonwords, regular and irregular words. Knowledge of grapheme phoneme correspondences is encoded in the weights on the connections between processing units. The frequency and consistency interaction in PDP models is reflected in the strength of the weights to number of exposures and regularity of the mappings.

AoA also interacts with the regularity of grapheme-phoneme conversions. In Chapter Five of the present thesis AoA effects interacted across languages with larger AoA effects in English (a relatively irregular orthography) than in Spanish (a relatively regular orthography). This finding is similar to the interaction found by Monaghan and Ellis (2000a, 2000b) that showed larger AoA effects for exception words than for regular words.

The challenge today for models such as the PDP and DRC models is to incorporate the order of word acquisition into the configuration of their simulations. Ellis and Lambon Ralph (2000) have recently demonstrated that the AoA effect can be implemented in a connectionist network without suffering catastrophic interference effects with the use of cumulative interleaved training. The current work has also provided experimental support for two locus of the AoA effect. The loci postulated by Ellis and Lambon Ralph (2000) in the connections between representations could be modelled in a PDP model using different weights values for early and late acquired words. The lemma level suggested by Gerhand and Barry (2000) could be implemented in a DRC model as a property of the lexical representations of the lexical route.

The present thesis has shown for the first time AoA effects in an array of lexical tasks in a second language acquired during adulthood. Bilingual models of word recognition and production are not as developed as their monolingual counterparts. Thus, the main claim of the bilingual interactive activation (BIA) model discussed in the introduction is that the bilingual's lexicon is integrated and that lexical access is not language selective with candidates in both language activated whenever the input shares features with alternatives in either language. The BIA model accounts for a number of different bilingual phenomena such as neighbourhood effects across languages, cognates, and homograph effects. In the BIA model word frequency and the relative frequency associated with each language is implemented varying the resting levels of activation. In a similar way the BIA model could perhaps implement L1 AoA and L2 AoA effects in word processing.

Until this and other bilingual and monolingual models of lexical processing do incorporate AoA effects into their accounts of word processing the models will be deficient at explaining a fundamental phenomenon of lexical processing. Without the risk of catastrophic interference effects, AoA can and must be incorporated into any model attempting to explain L1 and L2 processes.

7.5.2 Further investigation of the AoA effect in language attrition and implications of the AoA effect in second language learners

The present thesis has argued that AoA effects are not due to the age of word acquisition but to the order of vocabulary learning. AoA effects were observed in L1 and L2 and importantly L1 AoA and L2

AoA are independent variables that influence only the corresponding language. Words acquired first in L1 and L2 are processed faster in L1 and L2 than later acquired words. Monolingual research has also shown that early acquired words are less susceptible to brain damage. In healthy bilinguals first and second language attrition has been reported (Hansen, 2001) as the result of different sociolinguistic factors (e.g., use of L1 or L2, initial proficiency, motivation, etc.). An interesting matter for future research needs to investigate whether AoA affects language attrition and whether AoA would influence reactivation or re-learning of a 'lost' language. The arguments of the present thesis will predict a larger loss of late acquired words than early acquired words while faster recovery of early acquired words than late acquired words in a re-learning situation.

It is thought that educational programs related to second language vocabulary learning could benefit from the results of the present thesis. The teaching of basic vocabulary in a second language should take into account the fact that early acquired words are easier to access, faster to process and more durable to the effects of language attrition. Consequently educational programs could build a vocabulary knowledge that will facilitate second language learners to gain robust and effective communicative vocabulary from the start of their learning program.

7.5.3 Does L1 AoA and L2 AoA have independent effects on the recognition of cognates and false friends?

Cognates are those words that share orthographic form and meaning across two languages. An example of a cognate for Spanish and English languages is 'banana'. False friends (also called interlingual homographs) are words that share the same orthography but not the meaning across the bilingual's two languages. An example of false friends for the Spanish and English languages is 'red' meaning a colour name in English and a net in Spanish.

Since false friends and cognates share at least their orthographic representation across languages, the recognition process of these types of words might be more influenciable by characteristics of the non target language than the target language. In the present thesis independent L1 and L2 AoA effects were obtained for non-cognates and it was shown that a semantic location for these type of words is unlikely. Interesting further investigation might be to look at AoA on these types of words. Would cognates inherit the L1 AoA value? As cognates share the same meaning and word form it would be predictable that they will also share the same AoA value. However, would false friends, that only share the orthography across languages, be affected by the AoA of the non-target language?

7.5.4 The translation production task and AoA effects

The results of Chapter Six suggested that translation recognition processes are mediated by L1 and L2 AoA. An obvious extension of this line of research would be to look at AoA influences on translation production times.

It has been argued that each direction of translation (from L1 to L2 and from L2 to L1) is accomplished through a different lexico-semantic pathway. The revised hierarchical model, RHM (Kroll & Stewart, 1994) captures these different routes of translation. Kroll and Stewart (1994) proposed the RHM model to account for a number of results that the then available word association and concept mediation models could not explain. Some studies (Potter et al., 1984) had found that bilinguals were equally fast at naming pictures and translating words, a result in agreement with the concept mediation model. However, other studies (Kroll & Curley, 1988) found evidence for the word association model with faster translation times than picture naming times. To account for these contradictory results the RHM model suggested that early reliance on L1 lexical forms to access the meaning of L2 words created an asymmetry in the interlanguage connections. Although direct conceptual processing becomes increasingly possible for L2 words, L2 is less effective than L1 at directly engaging semantics. The lexical connections formed at the early stages of L2 acquisition are proposed to remain active as an alternative form of interlanguage connection. Regarding translation tasks, the model proposes that while translating from L1 to L2 is conceptually mediated, translating from L2 to L1 is not. According to the model translation from L2 to L1 is accomplished through a lexical route that connects L2 word forms with L1 word forms directly.

If the assumptions of the RHM hold true it could be possible to disentangle the two possible AoA loci postulated by the present thesis (lemma representation or connections between representations) using the translation production task. I will consider first AoA as a property of the connections between representations as suggested by Ellis and Lambon Ralph (2000). Translating from L1 to L2 requires an initial access to the meanings of L1 words and a subsequent access to the L2 words from the activated meanings. These two stages involve the connections between L1 and their semantic representations and the connections between the semantic representations and their coresponding L2 word forms. Therefore if AoA effects emerge from the connections between representations L1 and L2 AoA effects would be observable when translating from L1 to L2. However, according to the RHM translating from L2 to L1 is lexically mediated. This pathway only requires the direct connections between L2 and L1 and these links are created at the time of L2 learning therefore if AoA rests on these connections only an L2 AoA effect would be expected when translating from L2 to L1. If, on the other hand, AoA is located at the lemma level L1 and L2 AoA effects would be predicted in both directions of translation since the two corresponding lemmas have to be consulted regardless of the direction of translation.

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Appendix 1 Words used in Experiment 1

English word	AoA	Log Freq	Object Familiarity	RT
		Early acquired items		
balloon	1.80	0.60	2.86	565
clown	2.10	0.60	2.09	547
cow	1.45	1.36	3.18	568
dog	1.30	1.85	4.05	523
ear	1.55	1.63	4.59	586
fork	1.95	1.11	4.55	526
frog	2.10	0.70	2.38	499
horse	1.75	1.93	2.82	519
moon	1.95	1.73	3.32	521
pencil	2.05	1.20	4.00	505
pig	1.65	1.28	2.36	474
rabbit	1.90	1.08	2.81	571
shoe	1.30	1.18	4.68	582
spoon	1.45	1.08	4.64	577
tree	1.50	1.86	4.50	575
wheel	2.10	1.46	2.68	596
M	1.74	1.29	3.47	546
S	0.29	0.43	0.94	37
		Late acquired items		
cap	2.45	1.45	2.91	594
carrot	2.25	0.60	4.23	572
chain	2.95	1.53	2.57	601
church	2.35	2.20	3.09	548
envelope	3.25	1.30	4.30	619
hammer	2.55	1.00	2.82	539
heart	2.50	2.16	3.09	591
key	2.40	1.85	4.68	511
leaf	2.15	1.20	3.41	602
necklace	2.55	0.48	2.86	573
onion	2.55	1.00	3.95	555
ring	2.50	1.56	3.82	537
strawberry	2.35	0.60	2.77	630
tie	2.45	1.30	2.91	581
umbrella	2.45	1.08	3.41	640
vase	3.45	0.70	2.50	571
M	2.57	1.25	3.33	579
S	0.35	0.53	0.67	36

Note: AoA = Age of acquisition, Log Freq = Logarithm transformation of word frequency, RT = Lexical decision reaction times.

Appendix 2 Words used in Experiment 2

Spanish word	English translation	AoA	Log Freq	Object Familiarity	RT
		Early acquired items			
globo	balloon	3.04	1.18	2.57	675
payaso	clown	3.44	0.85	1.86	671
vaca	cow	3.68	1.11	2.89	623
perro	dog	3.00	2.05	4.09	592
oreja	ear	3.29	1.56	4.49	584
tenedor	fork	3.14	0.85	4.75	641
rana	frog	3.91	0.78	1.99	561
caballo	horse	3.64	1.98	2.72	585
luna	moon	3.90	1.91	4.11	570
lápiz	pencil	3.48	1.04	4.65	597
cerdo	pig	3.77	1.26	2.38	573
conejo	rabbit	3.67	1.00	2.31	568
zapato	shoe	3.20	1.26	4.46	542
cuchara	spoon	3.16	0.70	4.72	632
árbol	tree	3.65	1.75	3.98	582
rueda	wheel	3.82	1.41	2.39	627
M		3.49	1.29	3.40	602
S		0.31	0.44	1.09	39
		Late acquired items			
gorra	cap	4.79	1.15	2.28	732
zanahoria	carrot	4.30	0.78	3.55	640
cadena	chain	5.06	1.08	2.04	684
iglesia	church	4.62	2.04	2.83	682
sobre	envelope	5.16	2.03	3.96	647
martillo	hammer	4.65	0.95	2.31	587
corazón	heart	4.27	2.28	3.67	659
llave	key	4.53	1.65	4.72	562
hoja	leaf	4.12	1.57	3.54	609
collar	necklace	4.44	1.18	3.26	628
cebolla	onion	5.06	1.28	3.68	658
anillo	ring	4.78	1.32	3.98	652
fresa	strawberry	4.08	0.70	3.51	603
corbata	tie	5.10	1.43	2.11	615
paraguas	umbrella	4.18	1.28	4.16	605
jarrón	vase	4.65	0.78	3.02	581
M		4.61	1.34	3.29	634
S		0.36	0.47	0.79	44

Note: AoA = Age of acquisition, Log Freq = Logarithm transformation of word frequency, RT = Lexical decision reaction times.

Appendix 3 Words used in Experiment 3

Spanish name	English translation	Spanish AoA	Log Freq	Object Familiarity	Visual Complexity	Name Agree't	No.of Syll's	RT
				Early acquired Spanish items				
gato	cat	3.33	1.85	3.67	2.71	100	2	867
gallina	chicken	3.43	1.30	2.46	3.41	95	3	947
vaca	cow	3.68	1.11	2.89	2.97	100	2	871
pato	duck	3.44	0.78	2.39	3.17	98	2	789
pez	fish	3.67	1.49	3.77	3.34	92	1	776
gafas	glasses	3.98	1.59	3.83	2.20	100	2	866
cuchillo	knife	3.12	1.40	4.60	1.49	94	3	802
luna	moon	3.90	1.91	4.12	1.14	100	2	918
pera	pear	3.65	1.04	3.66	1.19	100	2	1048
lápiz	pencil	3.48	1.04	4.65	1.68	84	2	981
cerdo	pig	3.77	1.26	2.38	3.17	92	2	934
conejo	rabbit	3.67	1.00	2.31	3.31	100	3	928
zapato	shoe	3.20	1.26	4.46	3.17	100	3	929
calcetín	sock	3.28	0.60	4.69	1.61	100	3	1092
cuchara	spoon	3.16	0.70	4.72	1.86	90	3	918
estrella	star	4.05	1.69	3.49	1.19	100	3	936
M		3.55	1.25	3.63	2.35	96.56	2.38	913
S		0.29	0.39	0.90	0.88	4.90	0.62	86
				Late acquired Spanish items				
flecha	arrow	4.90	0.95	3.03	1.08	92	2	914
botón	button	4.39	1.41	4.13	1.46	98	2	884
gorra	cap	4.79	1.15	2.28	1.76	90	2	1070
cadena	chain	5.06	1.08	2.04	2.31	95	3	950
guante	glove	4.38	1.11	3.76	2.44	92	2	959
martillo	hammer	4.65	0.95	2.31	2.36	97	3	922
bolso	handbag	4.72	1.30	3.88	2.61	95	2	851
plancha	iron	4.84	0.85	3.52	3.15	100	2	1021
jarra	jug	4.26	0.95	3.88	1.81	89	2	1000
escalera	ladder	4.24	1.82	2.71	2.08	95	4	862
hoja	leaf	4.12	1.57	3.54	2.42	94	2	1135
cebolla	onion	5.06	1.28	3.68	2.36	95	3	936
anillo	ring	4.78	1.32	3.98	1.64	90	3	930
regla	ruler	4.80	1.57	3.51	2.61	97	2	944
maleta	suitcase	4.54	1.40	3.28	3.19	97	3	967
corbata	tie	5.10	1.43	2.11	2.32	100	3	1038
M		4.66	1.26	3.23	2.23	94.75	2.50	961
S		0.31	0.27	0.72	0.57	3.42	0.63	76

Note: AoA = Age of acquisition, Log Freq = Logarithm transformation of word frequency, Name Agree't = Name agreement, No.of Syll's = Number of syllables, RT = Picture naming reaction times.

English name	English AoA	Log Freq	Object Familiarity	Visual Complexity	Name Agreement	No. of Syllables	RT
			Early acquired English items				
cat	12.00	1.62	4.00	2.60	100	1	1209
chicken	13.80	1.49	3.20	2.90	70	2	1046
cow	21.00	1.36	3.18	3.85	100	1	1075
duck	23.40	0.70	2.59	3.05	82	1	950
fish	13.20	1.91	3.09	2.95	100	1	1333
glasses	22.80	1.30	3.82	2.60	86	2	1122
knife	19.20	1.56	4.82	1.95	96	1	1051
moon	18.00	1.73	3.32	1.05	91	1	794
pear	23.33	0.48	3.23	1.20	100	1	983
pencil	13.20	1.20	4.00	2.05	100	2	968
pig	18.00	1.28	2.36	2.70	96	1	1138
rabbit	19.20	1.08	2.81	2.65	95	2	1304
shoe	17.40	1.18	4.68	3.20	100	1	902
sock	24.00	0.60	4.73	1.80	100	1	1047
spoon	20.40	1.08	4.64	1.90	91	1	993
star	16.80	1.73	3.09	1.00	96	1	1057
M	18.48	1.27	3.60	2.34	93.94	1.25	1061
S	3.03	0.41	0.80	0.82	8.43	0.45	140
			Late acquired English items				
arrow	41.68	0.95	3.27	1.60	100	2	1122
button	29.40	1.20	4.09	2.02	100	2	855
cap	40.42	1.45	2.91	2.18	91	1	1178
chain	60.63	1.53	2.57	2.50	96	1	1268
glove	31.58	0.78	2.91	2.70	91	1	1254
hammer	29.65	1.00	2.82	2.55	100	2	1008
handbag	25.80	0.95	3.00	2.70	70	2	1189
iron	32.40	1.84	3.05	3.25	100	2	1171
jug	57.18	0.95	3.23	1.85	100	1	1693
ladder	33.88	1.15	2.64	2.55	96	2	1249
leaf	50.82	1.20	3.41	2.75	100	1	1091
onion	36.00	1.00	3.95	2.85	100	2	1141
ring	28.20	1.56	3.82	2.55	95	1	1196
ruler	27.79	0.95	3.82	2.40	100	2	1189
suitcase	36.60	1.11	2.50	3.30	77	2	1210
tie	42.32	1.30	2.91	2.65	100	1	1342
M	37.77	1.18	3.18	2.53	94.75	1.56	1197
S	10.55	0.29	0.51	0.45	8.97	0.51	174

Note: AoA = Age of acquisition, Log Freq = Logarithm transformation of word frequency, No.of syllables = Number of syllables, RT = Picture naming reaction times.

Appendix 4 Words used in Experiment 4

Spanish word	English Translation	Spanish AoA	Log Freq	No of Phonemes	No.of Letters	RT
			Early acquired Spanish words			
árbol	tree	3.65	1.75	5	5	650
botella	bottle	3.67	1.77	6	7	593
caja	box	4.10	1.79	4	4	619
camión	truck	3.86	1.15	6	6	655
caracol	snail	3.88	1.08	7	7	659
escoba	broom	4.00	0.78	6	6	635
flor	flower	3.18	1.78	4	4	598
fresa	strawberry	4.08	0.70	5	5	559
gafas	glasses	3.98	1.59	5	5	637
gallina	chicken	3.43	1.30	6	7	630
globo	balloon	3.04	1.18	5	5	625
jarra	jug	4.26	0.95	4	5	603
jersey	jumper	3.83	1.04	6	6	734
pantalón	trousers	3.85	1.51	8	8	704
payaso	clown	3.44	0.85	6	6	673
rana	frog	3.91	0.78	4	4	680
sombrero	hat	4.15	1.65	8	8	695
tijeras	scissors	4.08	0.78	7	7	682
vela	candle	3.90	1.45	4	4	697
M		3.80	1.26	5.58	5.74	649
S		0.33	0.39	1.30	1.33	45
			Late acquired Spanish words			
araña	spider	4.59	1.00	5	5	730
ardilla	squirrel	4.80	1.36	6	7	705
bolso	handbag	4.72	1.30	5	5	631
chaleco	vest	5.78	1.28	6	7	670
collar	necklace	4.44	1.18	5	6	669
cometa	kite	4.62	1.28	6	6	728
corazón	heart	4.27	2.28	7	7	621
flecha	arrow	4.90	0.95	5	6	713
foca	seal	5.34	0.78	4	4	663
guante	glove	4.38	1.11	6	6	699
hacha	axe	4.81	0.90	3	5	848
iglesia	church	4.62	2.04	7	7	669
jarrón	vase	4.65	0.78	5	6	683
llave	key	4.53	1.65	4	5	579
percha	hanger	4.88	0.90	5	6	774
pincel	paintbrush	4.91	0.90	6	6	708
tren	train	4.37	1.75	4	4	598
vestido	dress	4.27	1.93	7	7	724
zanahoria	carrot	4.30	0.78	8	9	743
M		4.69	1.27	5.47	6.00	692
S		0.38	0.46	1.26	1.20	63

Appendix 4 (Continued)

English word	English AoA	Log Freq Celex	Log Freq H+J	No of Phonemes	No.of Letters	RT
			Early acquired English words			
cat	12.00	1.62	0.85	3	3	614
apple	12.60	1.28	1.34	4	5	604
pencil	13.20	1.20	1.96	6	6	599
ear	14.40	1.63	1.63	3	3	650
monkey	15.60	1.00	0.00	5	6	718
basket	17.40	1.28	1.18	6	6	618
shoe	17.40	1.18	0.90	2	4	734
moon	18.00	1.73	1.58	3	4	625
pig	18.00	1.28	1.58	3	3	627
rabbit	19.20	1.08	0.30	5	6	687
spoon	20.40	1.08	1.52	4	5	787
butterfly	22.20	0.78	1.23	7	9	778
knife	19.20	1.56	0.78	3	5	697
umbrella	18.00	1.08	0.90	7	8	668
duck	23.40	0.70	1.46	3	4	639
shirt	22.80	1.66	1.26	4	5	613
bear	24.60	0.85	0.00	3	4	654
sock	24.00	0.60	0.85	3	4	818
bell	25.20	0.11	0.90	3	4	651
M	18.82	1.14	1.06	4.05	4.95	684
S	4.11	0.42	0.54	1.51	1.61	88
			Late acquired English words			
skirt	27.00	1.32	1.53	4	5	923
ring	28.20	1.56	1.15	4	4	790
fork	30.00	1.11	1.58	4	4	795
sheep	38.40	1.32	0.60	3	5	871
onion	36.00	1.00	0.48	5	5	787
cigar	32.40	1.15	1.26	5	5	731
wheel	37.89	1.46	0.90	3	5	648
envelope	34.20	1.30	0.78	7	8	844
flag	35.40	1.00	1.18	4	4	823
suitcase	30.60	1.11	0.95	7	8	817
fox	37.80	1.04	0.90	3	3	871
crown	38.12	1.38	1.11	4	5	767
tie	42.32	1.30	0.48	2	3	710
hammer	29.65	1.00	1.84	5	6	675
brush	42.00	1.11	1.43	3	5	787
leaf	50.82	1.20	1.38	3	4	688
ladder	33.88	1.15	0.78	5	6	757
bow	51.00	1.18	1.36	3	3	719
chain	60.63	1.53	1.51	4	5	729
M	37.70	1.22	1.12	4.11	4.89	775
S	8.68	0.18	0.39	1.33	1.41	73

Note: AoA = age of acquisition, Log Freq Celex = Logarithm transformation of Celex frequency count, Log Freq H+J = Logarithm transformation of Hofland and Johansson's (1988) frequency count, No of phonemes = Number of phonemes, No of letters = Number of letters, RT = Lexical decision reaction times.

Appendix 5 Words used in Experiment 5

Words	English AOA	Spanish AOA	Log Freq	Sqrt Imag	Log N	No. letters	RT
able	33.00	6.65	2.52	1.22	0.48	4	899
address	13.20	6.30	1.62	2.18	0.00	7	695
alone	20.40	4.30	2.29	1.96	0.60	5	631
although	39.00	6.30	2.48	1.07	0.00	8	758
always	19.80	5.45	2.82	1.24	0.30	6	596
anchor	47.29	5.61	0.78	2.56	0.00	6	852
answer	16.80	5.40	2.01	1.76	0.00	6	720
ant	39.60	3.25	0.70	2.43	1.08	3	785
apple	12.60	2.94	1.28	2.55	0.48	5	664
arrow	41.68	4.90	0.95	2.51	0.00	5	735
ashtray	54.32	4.86	0.00	2.36	0.00	7	947
axe	52.00	4.81	0.00	2.49	1.08	3	718
balloon	36.00	3.04	0.60	2.56	0.48	7	912
basket	17.40	4.49	1.28	2.57	0.95	6	720
bear	24.60	4.10	0.85	2.53	1.38	4	640
bed	12.60	2.49	2.39	2.56	1.28	3	651
bee	37.26	4.30	0.90	2.51	0.90	3	773
beer	27.00	5.25	1.67	2.63	0.85	4	716
bell	25.20	4.31	0.11	2.57	1.30	4	652
best	24.00	5.15	2.46	1.75	1.00	4	718
biscuit	23.40	2.75	0.78	2.47	0.00	7	700
boat	24.60	3.30	1.76	2.62	0.60	4	673
book	12.60	3.62	2.43	2.46	1.26	4	610
bottle	16.80	3.67	1.92	2.52	0.70	6	720
box	18.60	4.10	1.60	2.37	1.26	3	590
break	29.40	5.70	1.43	2.05	0.85	5	712
broom	43.64	4.00	0.85	2.51	0.78	5	1144
brush	42.00	4.06	1.11	2.49	0.78	5	643
bubble	46.20	4.60	0.70	2.58	0.85	6	868
business	39.00	6.90	2.37	2.05	0.30	8	842
butterfly	22.20	4.42	0.78	2.50	0.00	9	756
candle	36.60	3.90	0.95	2.64	0.85	6	723
cap	40.42	4.79	1.45	2.43	1.34	3	730
car	12.60	3.51	2.44	2.58	1.40	3	638
carpet	36.60	6.95	1.38	2.58	0.48	6	640
carrot	27.60	4.30	0.60	2.63	0.90	6	714
cat	12.00	3.33	1.62	2.53	1.48	3	553
century	36.60	7.05	2.26	1.69	0.00	7	666
chair	13.20	3.37	2.02	2.54	0.48	5	652
cheap	19.20	5.55	1.60	1.69	0.48	5	772
cheek	41.68	5.95	1.40	2.40	0.70	5	812
cherry	41.05	4.06	0.78	2.60	0.60	6	737
chicken	13.80	3.43	1.49	2.64	0.48	7	640
chilly	60.00	3.05	0.78	2.18	0.48	6	769
christmas	15.00	3.45	1.78	2.40	0.00	9	707
church	16.20	4.62	2.20	2.57	0.00	6	596
city	12.60	4.25	2.30	2.52	0.48	4	615
cloud	23.40	3.15	1.49	2.57	0.60	5	768
clown	37.80	3.44	0.60	2.59	0.60	5	646
coin	21.00	4.50	0.90	2.59	0.95	4	665
comb	45.23	3.78	0.70	2.48	0.78	4	803
cough	42.00	3.45	1.08	2.06	0.90	5	828
council	52.80	7.00	2.01	1.83	0.00	7	697
country	16.80	5.35	2.53	2.25	0.00	7	661
cow	21.00	3.68	1.36	2.63	1.45	3	695
crown	38.12	4.88	1.38	2.57	0.95	5	730

cup	18.60	3.23	1.78	2.55	1.23	3	683
dead	21.00	5.05	2.17	1.75	1.11	4	706
deep	37.80	7.00	0.60	1.82	1.00	4	677
dog	12.00	3.00	1.85	2.58	1.38	3	577
doll	30.60	2.85	1.26	2.57	1.08	4	688
donkey	28.42	3.10	1.00	2.62	0.30	6	756
door	12.60	3.50	2.52	2.44	1.04	4	624
drawer	40.42	3.70	1.20	2.36	0.30	6	772
dress	18.60	4.27	1.88	2.47	0.85	5	635
drum	39.33	4.60	0.90	2.57	0.90	4	768
duck	23.40	3.44	0.70	2.52	1.20	4	768
ear	14.40	3.29	1.63	2.49	1.32	3	721
easy	14.40	3.85	1.00	1.36	0.48	4	640
empty	19.80	5.45	0.00	1.99	0.00	5	716
end	13.20	4.35	2.61	1.76	0.30	3	636
every	15.60	5.55	2.74	1.26	0.30	5	638
expensive	18.60	5.20	1.85	1.67	0.48	9	773
eye	13.20	3.02	2.11	2.60	1.04	3	723
fact	42.00	5.65	2.71	1.32	0.85	4	628
fairy	51.60	4.15	1.08	2.51	0.70	5	768
farm	22.80	4.20	1.82	2.57	0.90	4	651
fear	43.20	3.16	2.06	1.69	1.11	4	628
fish	13.20	3.67	1.91	2.63	1.04	4	622
flag	35.40	4.85	1.00	2.52	1.08	4	735
flower	15.60	3.18	1.45	2.59	0.70	6	744
forehead	42.95	4.40	1.40	2.57	0.30	8	954
fork	30.00	3.14	1.11	2.52	1.04	4	710
fox	37.80	4.66	1.04	2.63	1.00	3	648
freedom	34.20	6.60	2.00	1.86	0.00	7	625
frog	36.60	3.91	0.70	2.52	0.95	4	675
frost	43.20	5.85	0.95	2.32	0.48	5	790
gentleman	26.40	5.70	1.41	2.30	0.30	9	718
ghost	30.60	3.35	1.32	2.33	0.00	5	810
gift	37.20	3.55	1.51	2.29	0.90	4	644
glass	19.80	2.98	2.10	2.45	0.70	5	621
glasses	22.80	3.98	1.30	2.50	0.00	7	663
glove	31.58	4.38	0.78	2.44	0.90	5	737
great	27.60	2.45	2.81	1.52	0.48	5	699
grocer	39.16	6.40	0.70	2.36	0.30	6	879
hammer	29.65	4.65	1.00	2.47	0.90	6	743
hand	13.20	3.17	2.64	2.51	1.20	4	660
handbag	25.80	4.72	0.95	2.41	0.30	7	819
hanger	48.00	4.88	0.30	2.38	0.95	6	942
hat	14.40	4.15	1.73	2.57	1.48	3	659
health	34.20	5.95	2.12	1.66	0.48	6	676
heart	24.00	4.27	2.16	2.59	0.48	5	679
horse	14.40	3.64	1.93	2.59	1.18	5	617
hundred	16.20	5.45	2.30	2.02	0.00	7	743
hunger	32.84	3.05	1.40	1.90	0.70	6	710
hunter	43.33	4.95	1.08	2.36	0.78	6	764
iron	32.40	4.84	1.84	2.41	0.30	4	627
jelly	54.75	6.45	1.04	2.45	0.90	5	848
journal	36.00	5.00	1.28	2.33	0.00	7	782
jug	57.18	4.26	0.95	2.51	1.26	3	874
jumper	35.40	3.83	0.30	2.49	0.70	6	694
kettle	41.33	6.50	1.08	2.50	0.90	6	739
key	18.00	4.53	1.85	2.50	1.20	3	607
kid	22.20	2.15	1.48	2.44	1.04	3	704
king	16.20	3.35	1.95	2.52	1.18	4	608
knife	19.20	3.12	1.56	2.57	0.30	5	676
ladder	33.88	4.24	1.15	2.59	0.95	6	792
leaf	50.82	4.12	1.20	2.54	1.11	4	764
learn	19.80	4.50	1.49	1.58	0.30	5	637
level	26.40	6.95	2.26	1.82	0.70	5	654

library	21.60	6.15	1.73	2.48	0.00	7	640
lorry	36.71	3.86	0.95	2.59	0.78	5	855
market	22.80	5.90	2.12	2.53	0.48	6	614
mister	22.11	4.10	0.70	1.88	0.78	6	645
monkey	15.60	4.40	1.00	2.54	0.48	6	638
moon	18.00	3.90	1.73	2.58	1.26	4	682
mushroom	40.80	5.25	0.78	2.48	0.00	8	740
necklace	48.67	4.44	0.48	2.51	0.00	8	945
needle	52.67	5.00	1.00	2.46	0.00	6	751
never	16.20	5.75	2.95	1.34	0.70	5	662
next	17.40	7.20	1.75	1.48	0.70	4	715
nose	15.60	3.32	1.87	2.41	1.15	4	713
nun	47.33	5.20	0.78	2.49	1.18	3	768
nut	55.80	5.00	0.90	2.39	1.20	3	752
onion	36.00	5.06	1.00	2.49	0.48	5	751
paintbrush	43.80	5.65	0.00	2.53	0.00	10	1021
pear	27.33	3.20	0.48	2.48	1.32	4	727
pearl	40.67	6.00	0.85	2.57	0.30	5	729
pencil	13.20	3.48	1.20	2.52	0.30	6	594
penny	27.16	7.85	1.18	2.54	0.48	5	644
pie	40.20	3.25	1.15	2.62	1.08	3	728
pig	18.00	3.77	1.28	2.60	1.15	3	613
pineapple	30.60	4.83	0.48	2.50	0.00	9	738
pleasure	39.60	7.30	1.92	1.95	0.00	8	686
pound	26.53	7.65	1.64	2.33	0.90	5	666
prize	29.40	4.55	1.28	2.22	0.60	5	628
pub	27.60	4.75	1.34	2.58	1.11	3	616
punishment	46.74	4.20	1.52	1.90	0.00	10	804
rabbit	19.20	3.67	1.08	2.57	0.60	6	666
rent	40.20	7.30	1.58	1.70	1.26	4	681
ring	28.20	4.78	1.56	2.44	1.08	4	619
rocket	45.88	5.35	0.95	2.56	1.04	6	793
rubber	24.60	4.60	1.41	2.25	0.48	6	844
ruler	27.79	4.80	0.95	2.40	0.00	5	737
sale	30.60	6.80	1.54	1.86	1.30	4	675
scissors	30.00	4.08	0.70	2.47	0.00	8	828
seed	49.33	5.50	1.46	2.46	1.32	4	745
sheep	38.40	3.88	1.32	2.53	1.00	5	665
shell	41.05	4.40	1.46	2.41	1.04	5	716
shirt	22.80	4.20	1.66	2.51	0.95	5	715
shoe	17.40	3.20	1.18	2.53	0.90	4	690
silly	22.80	2.45	1.65	1.63	0.90	5	647
skirt	27.00	4.10	1.32	2.46	0.70	5	742
slang	57.88	8.00	0.60	1.41	0.78	5	894
slippers	64.67	3.40	0.95	2.54	0.78	8	966
snail	36.00	3.88	0.60	2.50	0.60	5	847
sock	24.00	3.28	0.60	2.49	1.15	4	774
soul	38.40	6.85	1.62	1.67	0.70	4	656
speaker	28.80	7.85	1.26	2.19	0.30	7	741
spider	25.80	4.59	0.70	2.62	0.70	6	709
spoon	20.40	3.16	1.08	2.62	0.90	5	684
squirrel	50.00	4.80	0.70	2.61	0.00	8	951
star	16.80	4.04	1.73	2.61	1.04	4	616
strawberry	30.00	4.08	0.60	2.62	0.00	10	775
success	42.60	7.05	2.01	1.61	0.00	7	661
suitcase	30.60	4.54	1.11	2.64	0.00	8	683
sun	12.00	3.08	2.18	2.62	1.30	3	640
swan	53.33	5.11	0.78	2.64	1.00	4	911
swing	46.00	3.15	1.27	2.48	0.90	5	690
table	12.00	3.55	2.31	2.64	0.85	5	667
tap	50.82	4.80	1.20	2.58	1.41	3	774
tax	46.11	7.75	2.04	1.77	1.32	3	668
thirsty	24.60	6.70	0.78	1.84	0.30	7	699
thousand	16.80	7.50	2.06	1.90	0.00	8	724

tidy	32.67	5.85	0.95	1.94	0.48	4	729
tie	42.32	5.10	1.30	2.58	1.28	3	739
tortoise	39.53	3.85	0.70	2.62	0.00	8	917
travel	20.40	4.80	1.48	2.10	0.30	6	888
tree	12.60	3.65	1.86	2.63	1.08	4	650
trousers	16.20	3.85	1.46	2.59	0.30	8	1068
ugly	21.60	2.60	1.38	2.20	0.00	4	674
umbrella	18.00	4.18	1.08	2.63	0.00	8	696
village	26.40	4.20	2.13	2.49	0.48	7	656
wasp	56.25	4.50	0.48	2.58	0.90	4	787
welcome	16.20	6.65	0.78	1.77	0.00	7	617
wheel	37.89	3.82	1.46	2.63	0.30	5	688
window	13.20	3.88	2.12	2.63	0.30	6	634
witch	50.12	2.80	1.23	2.55	0.95	5	826
wizard	55.06	3.80	0.48	2.55	0.30	6	779

Note: AoA = Age of acquisition, Log Freq = Logarithm transformation of word frequency, Sqrt Imag = Square root transformation of imageability, Log N = Logarithm transformation of number of orthographic neigbours, No letter = Number of letters, RT = Lexical decision reaction time.

Appendix 6 Words used in Experiment 6

English word	Spanish word	Eng AoA	Span AoA	Eng freq (Celex)	Eng freq (K-F)	Span freq	Eng imag	Span imag	Eng L	Span L	Eng RT	Span RT
					Early Spanish / Late English							
brush	cepillo	42.00	4.06	1.11	1.65	0.95	6.20	6.83	5	7	695	621
cherry	cereza	41.05	4.06	0.78	0.85	0.78	6.75	6.96	6	6	752	649
chilly	frio	60.00	3.05	0.78	0.78	2.12	4.75	4.65	6	4	827	619
cough	tos	42.00	3.45	1.08	0.90	1.08	4.25	4.96	5	3	858	637
doll	muñeca	30.60	2.85	1.26	1.04	1.23	6.60	6.96	4	6	805	656
donkey	burro	28.42	3.10	1.00	0.30	1.28	6.85	6.87	6	5	992	605
drawer	cajón	40.42	3.70	1.20	0.95	1.43	5.55	6.74	6	5	1017	686
fairy	hada	51.60	4.15	1.08	0.70	0.81	6.30	5.83	5	4	1002	744
fear	miedo	43.20	3.16	2.06	2.11	2.23	2.85	5.09	4	5	725	594
ghost	fantasma	30.60	3.35	1.32	1.08	1.36	5.45	5.70	5	8	735	710
gift	regalo	37.20	3.55	1.32	1.53	1.62	5.25	5.87	4	6	831	615
hunger	hambre	32.84	3.05	1.40	1.26	1.82	3.60	4.87	6	6	848	643
lorry	camión	36.71	3.86	0.95	0.00	1.15	6.70	6.91	5	6	889	632
onion	cebolla	36.00	4.20	1.00	1.20	1.28	6.20	6.87	5	7	693	589
punishment	castigo	46.74	4.20	1.52	1.34	1.48	3.60	5.04	10	7	1073	689
tortoise	tortuga	39.53	3.85	0.70	0.60	1.00	6.85	6.91	8	7	1137	667
witch	bruja	50.12	2.80	1.23	0.78	1.18	6.50	6.52	5	5	1201	676
slippers	zapatillas	64.67	3.40	0.95	0.60	1.29	6.45	6.87	8	10	979	626
M		41.87	3.55	1.15	0.98	1.34	5.59	6.14	5.7	5.9	892	648
S		9.84	0.48	0.32	0.50	0.40	1.28	0.87	1.5	1.6	154	41

Appendix 6 (continued)

English word	Spanish word	Eng AoA	Span AoA	Eng freq (Celex)	Eng freq (K-F)	Span freq	Eng imag	Span imag	Eng L	Span L	Eng RT	Span RT
					Late Spanish / Early English							
address	dirección	13.20	6.30	1.62	1.89	1.96	4.75	3.65	7	9	739	742
basket	cesta	17.40	4.49	1.28	1.26	0.90	6.60	6.91	6	5	637	626
bell	campana	25.20	4.31	0.11	1.28	1.26	6.60	6.91	4	7	669	839
butterfly	mariposa	22.20	4.52	0.78	0.48	0.95	6.25	6.96	9	8	873	600
carrot	zanahoria	27.60	4.30	0.60	0.30	0.78	6.90	6.91	6	9	793	819
cheap	barato	19.20	5.55	1.60	1.40	1.13	2.85	3.96	5	6	697	651
coin	moneda	21.00	4.50	0.90	1.04	1.29	6.70	6.83	4	6	705	606
empty	vacío	19.80	5.45	0.00	1.81	0.40	3.95	3.96	5	5	748	629
expensive	caro	18.60	5.20	1.85	1.65	1.34	2.80	4.30	9	4	756	762
gentleman	caballero	26.40	5.70	1.41	1.46	1.81	5.30	6.26	9	9	882	652
handbag	bolso	25.80	4.72	0.95	0.00	1.30	5.80	6.91	7	5	842	634
key	llave	18.00	4.53	1.85	1.95	1.65	6.25	6.83	3	5	679	590
penny	penique	27.16	7.85	1.18	1.41	0.00	6.45	5.57	5	7	901	853
pound	libra	26.53	7.65	1.64	1.46	0.70	5.45	4.48	5	5	801	637
pub	bar	27.60	4.75	1.34	0.30	1.92	6.65	6.91	3	3	734	582
rubber	goma	24.60	4.60	1.41	1.20	1.13	5.05	6.74	6	4	822	637
ruler	regla	27.79	4.80	0.95	0.60	1.57	5.75	6.70	5	5	899	596
travel	viaje	20.40	4.80	1.48	1.79	2.17	4.40	6.13	6	5	650	587
M		22.69	5.22	1.16	1.18	1.24	5.47	5.94	5.7	5.9	768	669
S		4.39	1.06	0.54	0.60	0.57	1.28	1.25	1.8	1.8	87	91

Note: AoA = Age of acquisition, Eng freq (Celex) = Celex word frequency, Eng freq (K+F) = Kucera and Francis (1967) word frequency count, Span freq = Spanish word frequency, Eng imag = English imageability, Span imag = Spanish imageability, Eng L = English number of letters, Span L = Spanish number of letters, Eng RT = English reaction times. Span RT = Spanish reaction times.

Appendix 7 Words used in Experiment 7

English words						
Word	AoA	Log Freq	Imag	Log N	Syll	RT
			Set A Early			
bear	24.60	0.85	6.40	1.38	1	558
biscuit	23.40	0.70	6.10	0.00	2	509
box	18.60	1.60	5.60	1.26	1	504
cat	12.00	1.62	6.40	1.48	1	493
cloud	23.40	1.49	6.60	0.60	1	525
cow	21.00	1.36	6.90	1.45	1	567
ear	14.40	1.63	6.20	1.32	1	563
fish	13.20	1.91	6.89	1.04	1	463
glasses	22.20	1.30	6.25	0.00	2	570
hat	14.40	1.73	6.60	1.48	1	451
pig	18.00	0.00	6.75	1.15	1	506
shirt	22.20	1.66	6.30	0.95	1	491
skirt	27.00	1.32	6.05	0.70	1	550
spider	25.80	0.70	6.85	0.70	2	473
star	16.80	1.73	6.80	1.04	1	485
umbrella	18.00	1.08	6.90	0.00	3	576
M	19.69	1.29	6.47	0.91	1.31	517
S	4.68	0.51	0.38	0.53	0.60	41
			Set B Early			
apple	12.60	1.28	6.50	0.48	2	571
book	12.60	2.43	6.90	1.20	1	571
boat	24.60	1.76	6.85	0.60	1	551
chair	13.20	0.02	6.45	1.48	1	576
dog	12.00	1.85	6.65	1.38	1	566
duck	23.40	0.70	6.35	1.20	1	528
farm	22.20	1.82	6.60	0.90	1	527
horse	14.40	1.93	6.70	1.18	1	517
knife	19.20	1.56	6.60	0.30	1	591
monkey	15.60	1.00	6.45	0.48	2	538
nose	15.60	1.87	5.80	1.15	1	543
pencil	13.20	1.20	6.35	0.30	2	538
rabbit	19.20	1.08	6.60	0.60	2	567
shoe	17.40	1.18	6.40	0.90	1	495
spoon	20.40	1.08	6.85	0.90	1	591
ugly	21.60	1.34	6.43	0.79	2	582
M	17.33	1.38	6.43	0.82	1.31	553
S	4.24	0.57	0.50	0.43	0.48	28

English words

Word	AoA	Log Freq	Imag	Log N	Syll	RT
			Set A Late			
anchor	47.29	0.78	6.55	0.00	2	607
century	36.60	2.26	2.85	0.00	3	593
cheek	41.68	1.40	5.75	0.70	1	578
council	52.80	2.01	3.35	0.95	2	583
crown	38.12	1.38	6.60	0.90	1	578
drum	39.33	0.90	6.60	1.08	1	557
flag	35.40	1.00	6.35	1.00	1	476
fox	37.80	1.04	6.90	0.48	1	517
frost	43.20	0.95	5.40	0.30	1	564
glove	31.58	0.78	5.95	0.90	1	561
iron	32.40	1.84	5.80	0.00	2	524
prize	29.40	1.28	4.95	0.60	1	575
ruler	27.79	0.95	5.75	0.00	2	507
seed	49.33	1.46	6.05	1.32	1	501
success	42.60	2.01	2.60	0.00	2	543
tap	50.82	1.20	6.65	1.41	1	500
M	39.76	1.33	5.51	0.60	1.44	548
S	7.62	0.47	1.38	0.50	0.63	39
			Set B Late			
arrow	41.68	0.95	6.30	0.00	2	556
business	39.00	2.37	4.20	0.30	2	588
soul	38.40	1.62	2.80	0.70	1	552
nun	47.33	0.78	6.20	1.18	1	532
suitcase	30.60	1.11	6.95	0.00	2	607
forehead	42.95	1.40	6.60	0.30	2	515
hammer	29.65	1.00	6.10	0.90	2	510
hunter	43.33	1.08	5.55	0.78	2	567
jelly	54.75	1.04	6.00	0.90	2	613
needle	52.67	1.00	6.05	0.00	2	650
pie	40.20	1.15	6.85	1.08	1	502
sheep	38.40	1.32	6.40	1.00	1	525
cap	40.42	1.45	5.90	1.34	1	617
swan	53.33	0.78	6.95	1.00	1	550
tax	46.11	2.04	3.15	1.32	1	572
tie	42.32	1.30	6.65	1.28	1	542
M	42.57	1.27	5.79	0.76	1.44	562
S	7.17	0.43	1.28	0.48	0.51	43

Note: AoA = Age of acquisition, Log Freq = Logarithm transformation of word frequency, Imag = Imageability, Log N = Logarithm transformation of number of neighbours, Syll = Number of syllables, RT = reading reaction times.

Spanish words						
Word	AoA	Log Freq	Imag	Log N	Syll	RT
			Set A Early			
barco	3.30	1.72	6.90	0.95	2	535
caballo	3.64	1.98	5.43	0.48	3	524
conejo	3.20	0.98	5.88	0.60	3	500
cuchara	2.80	0.65	6.96	0.78	3	500
cuchillo	3.12	1.39	6.01	0.48	3	567
feo	2.60	1.41	5.70	0.78	2	475
granja	4.20	0.90	6.89	0.60	2	512
lápiz	3.20	1.04	5.87	0.00	2	509
libro	3.62	2.45	6.83	0.70	2	503
manzana	2.94	1.10	6.96	0.48	3	487
mono	2.95	1.40	6.99	1.32	2	482
nariz	2.45	1.85	6.10	0.48	2	496
pato	3.44	0.78	6.83	1.32	2	485
perro	3.00	2.05	6.62	0.90	2	435
silla	3.37	1.83	6.18	1.04	2	439
zapato	2.95	1.24	6.63	0.60	3	499
M	3.17	1.42	6.42	0.72	2.38	496
S	0.43	0.51	0.53	0.34	0.50	32
			Set B Early			
oso	4.10	1.38	6.99	0.95	2	482
galleta	2.75	0.48	6.83	0.78	3	507
caja	4.10	1.79	6.47	1.38	2	470
gato	3.33	1.85	6.44	1.11	2	481
nube	3.15	1.41	6.54	0.48	2	514
vaca	3.68	1.11	6.91	1.26	2	500
oreja	3.29	1.55	6.65	0.30	3	536
pescado	3.67	1.38	6.66	0.30	3	513
gafas	3.98	1.59	6.91	1.15	2	509
sombrero	4.15	1.65	5.92	0.00	3	534
cerdo	3.77	1.26	6.83	0.78	2	537
camisa	3.65	1.79	6.58	0.60	3	505
falda	3.85	1.58	6.72	1.00	2	507
araña	3.95	1.00	6.96	1.00	3	501
estrella	3.15	1.69	6.28	0.60	3	484
paraguas	3.25	1.27	6.96	0.48	3	509
M	3.61	1.42	6.67	0.76	2.50	505
S	0.42	0.35	0.29	0.39	0.52	20

Word	AoA	Log Freq	Imag	Log N	Syll	RT
Spanish words						
Set A Late						
aguja	5.00	1.22	6.14	0.48	3	561
alma	6.85	2.22	3.12	0.95	2	513
cazador	4.95	1.16	6.65	0.78	3	523
cisne	4.55	0.78	6.96	0.00	3	506
corbata	4.80	1.42	6.33	0.48	3	515
flecha	4.90	0.93	5.73	0.70	2	536
frente	4.40	2.58	6.07	0.30	2	482
gelatina	6.45	0.54	6.48	0.00	4	560
gorra	4.79	1.15	6.96	1.15	3	569
impuesto	7.75	1.38	5.00	0.30	3	518
maleta	4.80	1.39	6.96	0.85	3	527
martillo	4.65	0.93	6.18	0.48	3	539
monja	5.20	1.22	6.65	0.70	2	503
negocio	6.90	1.75	4.90	0.48	3	465
oveja	5.35	0.78	6.83	0.30	3	501
pastel	4.79	1.02	6.78	0.78	2	496
M	5.38	1.28	6.11	0.55	2.63	519
S	1.01	0.53	1.02	0.32	0.62	29
Set B Late						
ancla	5.61	0.88	6.48	0.70	2	519
éxito	7.05	1.98	4.25	0.85	3	490
mejilla	5.95	1.23	6.39	0.48	3	535
corona	4.88	1.34	5.78	0.90	3	491
tambor	4.60	1.08	6.91	0.30	2	528
bandera	4.85	1.52	5.71	0.30	3	471
zorro	4.66	0.85	6.91	1.11	2	493
helada	5.85	1.28	4.91	1.00	3	542
plancha	4.84	0.85	6.78	0.48	2	524
guante	4.38	1.11	5.91	0.00	2	493
ayuntamiento	7.00	1.08	5.02	0.30	5	499
premio	4.55	1.64	5.69	0.85	2	519
regla	4.50	1.56	5.65	0.60	2	501
semilla	5.50	1.04	6.03	0.48	3	476
siglo	7.05	2.43	4.65	0.30	2	508
grifo	4.80	1.06	6.68	0.60	2	420
M	5.38	1.31	5.86	0.58	2.56	500
S	0.95	0.43	0.82	0.31	0.81	30

Note: AoA = Age of acquisition, Log Freq = Logarithm transformation of word frequency, Imag = Imageability, Log N = Logarithm transformation of number of neighbours, Syll = Number of syllables, RT = Reading reaction times.

Appendix 8 Words used in Experiment 8 and 9

English words									
Word	L1 AoA	L2 AoA	Log Freq	Imag	Log N	Let	Exp 8 L1 RT	Exp 8 L2 RT	Exp 9 L1 RT
Early									
apple	1.25	12.60	1.28	6.50	0.30	5	495	574	276
bear	1.81	24.60	0.85	6.40	1.38	4	511	638	297
biscuit	1.69	23.40	0.70	6.10	0.00	7	484	674	361
boat	1.63	24.60	1.76	6.85	0.60	4	478	623	362
chair	1.81	13.20	0.02	6.45	1.48	5	521	668	375
cloud	2.25	23.40	1.49	6.60	0.48	5	519	649	335
duck	1.56	23.40	0.70	6.35	1.20	4	486	611	328
ear	1.81	14.40	1.63	6.20	1.32	3	504	635	329
farm	2.06	22.20	1.82	6.60	0.90	4	515	618	385
fish	1.69	13.20	1.91	6.89	1.04	4	485	630	378
hat	1.69	14.40	1.73	6.60	1.48	3	487	606	358
horse	1.63	14.40	1.93	6.70	1.18	5	467	623	345
knife	2.19	19.20	1.56	6.60	0.30	5	494	648	351
nose	1.44	15.60	1.87	5.80	1.04	4	483	631	311
pencil	2.19	13.20	1.20	6.35	0.30	6	479	617	376
pig	1.63	18.00	0.00	6.75	1.15	3	463	593	349
rabbit	1.63	19.20	1.08	6.60	0.30	6	483	610	352
shoe	1.69	17.40	1.18	6.40	0.60	4	546	694	315
spoon	1.44	20.40	1.08	6.85	0.70	5	558	666	435
star	2.06	16.80	1.73	6.80	1.04	4	549	674	360
M	1.76	18.18	1.28	6.52	0.84	4.50	500	634	349
S	0.27	4.26	0.59	0.28	0.46	1.05	27	30	35
Late									
anchor	3.31	47.29	0.78	6.55	0.00	6	524	692	279
arrow	2.88	41.68	0.95	6.30	0.00	5	517	641	352
business	4.06	39.00	2.37	4.20	0.30	8	511	688	330
cap	2.31	40.42	1.45	5.90	1.34	3	541	616	344
crown	2.56	38.12	1.38	6.60	0.95	5	499	608	339
flag	2.88	35.40	1.00	6.35	1.08	4	496	631	382
forehead	3.00	42.95	1.40	6.60	0.30	8	538	779	305
frost	3.25	43.20	0.95	5.40	0.60	5	498	643	317
hammer	2.63	29.65	1.00	6.10	0.90	6	520	662	401
hunter	3.50	43.33	1.08	5.55	0.78	6	512	673	314
needle	2.81	52.67	1.00	6.05	0.00	6	507	632	308
nun	3.69	47.33	0.78	6.20	1.18	3	500	667	340
prize	3.00	29.40	1.28	4.95	0.60	5	470	603	368
ruler	2.88	27.79	0.95	5.75	0.00	5	493	631	390
seed	2.81	49.33	1.46	6.05	1.32	4	556	699	306
soul	5.00	38.40	1.62	2.80	0.70	4	573	678	398
success	4.56	42.60	2.01	2.60	0.00	7	527	680	351
swan	2.56	53.33	0.78	6.95	1.00	4	543	679	338
tax	5.38	46.11	2.04	3.15	1.32	3	502	612	332
tie	2.63	42.32	1.30	6.65	1.28	3	510	616	368
M	3.29	41.52	1.28	5.05	0.68	5.05	517	657	343
S	0.85	7.13	0.45	1.50	0.51	1.50	24	42	34

Note: L1 = First language, L2 = Second langauge, AoA = Age of acquisition, Log Freq = Logarithm transformation of word frequency, Imag = Imageability, Log N = Logarithm transformation of number of neighbours, Let = Number of letters, Exp = Experiment, RT = Reading reaction times.

Word	L1 AoA	Log Freq	Imag	Log N	Let	Exp 8 RT	Exp 9 RT
Spanish words							
Early							
manzana	2.94	1.10	6.96	0.48	7	476	357
oso	4.10	1.38	6.99	0.95	3	460	352
galleta	2.75	0.48	6.83	0.78	7	500	415
barco	3.30	1.72	6.90	0.95	5	472	326
silla	3.37	1.83	6.18	1.04	5	537	411
nube	3.15	1.41	6.54	0.48	4	518	331
pato	3.44	0.78	6.83	1.32	4	519	418
oreja	3.29	1.55	6.65	0.30	5	495	336
granja	4.20	0.90	6.89	0.60	6	510	330
pescado	3.67	1.38	6.66	0.30	7	482	367
sombrero	4.15	1.65	5.92	0.00	8	487	350
caballo	3.64	1.98	5.43	0.48	7	482	368
cuchillo	3.12	1.39	6.01	0.48	8	498	323
nariz	2.45	1.85	6.10	0.48	5	450	306
lápiz	3.20	1.04	5.87	0.30	5	438	370
cerdo	3.77	1.26	6.83	0.78	5	488	380
conejo	3.20	0.98	5.88	0.60	6	475	330
zapato	2.95	1.24	6.63	0.60	6	523	464
cuchara	2.80	0.65	6.96	0.78	7	525	369
estrella	3.15	1.69	6.28	0.60	8	491	382
M	3.49	1.31	6.47	0.60	5.85	491	364
S	0.41	0.42	0.47	0.33	1.42	26	39
Late							
ancla	5.61	0.88	6.48	0.70	5	496	343
flecha	4.90	0.93	5.73	0.70	6	466	329
negocio	6.90	1.75	4.90	0.48	7	485	373
gorra	4.79	1.15	6.96	1.15	5	492	393
corona	4.88	1.34	5.78	1.04	6	487	346
bandera	4.85	1.52	5.71	0.48	7	523	385
frente	4.40	2.58	6.07	0.30	6	480	334
helada	5.85	1.28	4.91	1.15	6	491	336
martillo	4.65	0.93	6.18	0.48	8	467	315
cazador	4.95	1.16	6.65	0.78	7	544	382
aguja	5.00	1.22	6.14	0.48	5	496	369
monja	5.20	1.22	6.65	0.70	5	494	380
premio	4.55	1.64	5.69	0.85	6	493	363
regla	4.50	1.56	5.65	0.60	5	541	402
semilla	5.50	1.04	6.03	0.48	7	492	383
alma	6.85	2.22	3.12	1.15	4	489	306
éxito	7.05	1.98	4.25	0.85	5	513	351
cisne	4.55	0.78	6.96	0.00	5	480	375
impuesto	7.75	1.38	5.00	0.30	8	507	369
corbata	4.80	1.42	6.33	0.48	7	514	387
M	5.43	1.40	5.76	0.66	6.00	497	361
S	0.95	0.46	0.95	0.31	1.12	21	27

Note: L1 = First language, AoA = Age of acquisition, Log Freq = Logarithm transformation of word frequency, Imag = Imageability, Log N = Logarithm transformation of number of neighbours, Let = number of letters, Exp = Experiment, RT = Reading reaction times.

Appendix 9 Words used in Experiment 10, 11, and 12

Translation pairs	Eng Imag	Sp imag	En AoA	Sp AoA	En K& F	En Celex	Sp Fr	Eng L	Sp L	Trans Accy	Exp10 RT	Exp11 En RT	Exp11 Sp RT	Exp12 RT
English Early / Spanish Early														
Horse - caballo	6.70	6.74	14.40	3.64	2.07	1.95	1.98	5	7	1.00	813	754	598	633
Box- caja	5.60	6.65	18.60	4.10	1.85	1.91	1.80	3	4	1.00	743	637	569	583
Sock - calcetín	6.20	6.78	24.00	3.25	0.70	0.60	0.60	4	8	1.20	892	740	652	599
Rabbit - conejo	6.60	6.91	19.20	3.20	1.08	1.08	0.98	6	6	1.05	824	621	622	565
Easy - fácil	1.85	2.65	14.40	3.85	2.10	2.18	2.15	4	5	1.05	841	607	626	641
Skirt - falda	6.05	6.87	27.00	3.85	1.34	1.34	1.58	5	5	1.00	861	667	664	580
Glasses - gafas	6.25	6.91	22.80	3.98	0.00	1.75	1.59	7	5	1.05	807	618	614	649
Biscuit - galleta	6.10	6.83	23.40	2.75	0.48	0.78	0.48	7	7	1.25	808	929	658	637
Pencil - lápiz	6.35	6.91	13.20	3.20	1.54	1.23	1.04	6	5	1.00	860	762	575	610
Xmas - navidad	5.75	6.26	15.00	3.45	1.45	1.76	1.45	9	7	1.00	882	630	622	560
Trousers-pantalones	6.70	6.91	16.20	4.18	0.90	1.48	1.64	8	10	1.00	885	619	633	606
Duck - pato	6.35	6.83	23.40	3.44	1.00	0.95	0.78	4	4	1.00	869	777	624	597
Village - pueblo	6.20	6.35	26.40	4.20	1.86	2.15	2.42	7	6	1.30	895	799	613	693
Mister - señor	3.55	6.48	22.11	4.10	1.04	0.90	2.50	6	5	1.15	952	824	657	653
Silly - tonto	2.65	4.70	22.80	2.45	1.20	1.66	1.32	5	5	1.25	935	729	622	615
Shoe - zapato	6.40	6.96	17.40	2.95	1.18	1.20	1.24	4	6	1.00	874	676	674	672
M	5.58	6.36	20.02	3.54	1.24	1.43	1.47	5.63	5.94	1.08	859	712	626	618
S	1.50	1.13	4.52	0.54	0.58	0.50	0.61	1.67	1.57	0.11	52	93	30	38
English Early/ Spanish Late														
Cheap - barato	2.85	3.96	19.20	5.55	1.40	1.64	1.13	5	6	1.00	897	596	666	642
Library - biblioteca	6.15	6.87	21.60	6.15	1.80	1.72	1.52	7	10	1.00	986	647	687	622
Handbag - bolso	5.80	6.91	25.80	4.72	0.00	0.95	1.29	7	5	1.00	1044	853	621	680
Bell - campana	6.60	6.91	25.20	4.31	1.28	1.46	1.26	4	7	1.00	942	696	746	557
Basket - cesta	6.60	6.91	17.40	4.49	1.26	1.30	0.90	6	5	1.05	810	655	706	616
Rubber - goma	5.05	6.74	24.60	4.60	1.20	1.45	1.13	6	4	1.20	875	711	653	679
Church - iglesia	6.60	6.74	16.20	4.62	2.54	2.21	2.04	6	7	1.05	917	646	648	583
Pound - libra	5.45	4.48	26.53	7.65	1.46	1.62	0.70	5	5	1.25	851	644	651	600
Key - llave	6.25	6.83	18.00	4.53	1.95	1.87	1.65	3	5	1.00	852	866	624	702
Butterfly - mariposa	6.25	6.96	22.20	4.42	0.48	0.78	0.93	9	8	1.00	859	581	606	639
Coin - moneda	6.70	6.83	21.00	4.50	1.04	0.90	1.29	4	6	1.05	927	654	681	669
Dead - muerto	3.05	6.09	21.00	5.05	2.24	2.29	2.25	4	6	1.15	889	732	575	637
Ruler - regla	5.75	6.70	27.79	4.50	0.60	0.95	1.56	5	5	1.25	843	716	596	647
Thirsty - sediento	3.40	5.22	24.60	6.70	0.78	0.85	0.30	7	8	1.00	821	733	805	605
Travel - viaje	4.40	6.13	20.40	4.80	1.79	1.82	2.17	6	5	1.45	1065	766	682	664
Carrot - zanahoria	6.90	6.91	27.60	4.30	0.30	0.60	0.78	6	9	1.00	755	613	686	611
M	5.49	6.32	22.44	5.06	1.26	1.40	1.31	5.63	6.31	1.09	896	694	665	634
S	1.36	0.95	3.69	0.97	0.71	0.52	0.54	1.50	1.70	0.13	83	83	58	39

Appendix 9 (continued)

Translation pairs	Eng Imag	Sp Imag	En AoA	Sp AoA	En K& F	En Celex	Sp Freq	Eng L	Sp L	Trans Accy	Exp10 RT	Exp11 En RT	Exp11 Sp RT	Exp12 RT
							English Late/ Spanish Early							
Witch - bruja	6.50	6.52	50.12	2.80	0.78	1.23	1.18	5	5	1.10	889	661	605	603
Donkey - burro	6.85	6.87	28.42	3.10	0.30	1.04	1.28	6	5	1.00	874	823	614	694
Drawer - cajon	5.55	6.74	40.42	3.70	0.95	1.04	1.43	6	5	1.11	1019	797	681	676
Punishment-castigo	3.60	5.04	46.74	4.20	1.34	1.51	1.48	10	7	1.05	861	809	634	700
Onion - cebolla	6.20	6.87	36.00	4.25	1.20	1.04	2.25	5	7	1.00	1146	728	588	727
Brush - cepillo	6.20	6.83	42.00	4.06	1.65	1.26	0.95	5	7	1.70	929	714	642	658
Ladder - escalera	6.70	6.91	33.88	4.24	1.30	1.18	1.82	6	8	1.11	876	671	606	675
Ghost - fantasma	5.45	5.70	30.60	3.35	1.08	1.34	1.36	5	8	1.10	999	754	644	693
Hunger - hambre	3.60	4.87	32.84	3.05	1.26	1.41	1.82	6	6	1.55	905	767	677	647
Leaf - hoja	6.45	6.74	50.82	4.12	1.11	1.23	1.56	4	4	1.40	858	819	603	680
Jug - jarra	6.30	6.87	57.18	4.26	0.85	1.00	0.93	3	5	1.53	914	915	670	658
Fear - miedo	2.85	5.09	43.20	3.16	2.11	2.23	2.23	4	5	1.15	930	698	605	592
Gift - regalo	5.25	5.87	37.20	3.55	1.53	1.53	1.62	4	6	1.20	977	836	623	600
Wheel - rueda	6.90	6.91	37.89	3.40	1.76	1.46	1.41	5	5	1.11	948	979	623	674
Cough - tos	4.25	4.96	42.00	3.45	0.90	1.04	1.08	5	3	1.10	966	672	658	613
Slippers - zapatillas	6.45	6.87	64.67	3.40	0.60	0.95	1.29	8	10	1.25	1060	781	631	637
M	5.57	6.23	42.12	3.63	1.17	1.28	1.48	5.44	6.00	1.22	947	777	632	658
S	1.30	0.82	9.85	0.49	0.46	0.32	0.40	1.67	1.75	0.21	79	88	28	40
							English Late/ Spanish Late							
Needle - aguja	6.05	6.96	52.67	5.00	1.20	1.04	1.22	6	5	1.22	898	924	623	620
Flag - bandera	6.35	6.78	35.40	4.85	1.23	1.32	1.52	4	7	1.00	925	786	629	808
Hunter - cazador	5.55	6.65	43.33	4.95	1.28	1.11	1.16	6	7	1.00	876	621	619	816
Ashtray - cenicero	5.55	6.87	54.32	4.86	0.00	0.00	1.02	7	8	1.00	1045	856	666	660
Break - descanso	4.20	4.43	29.40	5.70	1.95	2.03	1.51	5	8	1.40	1047	619	682	721
Success - éxito	2.60	4.52	42.60	7.05	1.97	2.03	1.98	7	5	1.00	894	926	666	631
Forehead - frente	6.60	6.65	42.95	4.40	1.23	1.43	2.58	8	6	1.11	803	656	667	782
Axe - hacha	6.20	6.87	52.00	4.81	0.85	0.00	0.90	3	5	1.21	822	643	711	682
Freedom - libertad	3.45	5.09	34.20	6.60	2.11	2.02	2.27	7	8	1.00	1111	663	645	601
Suitcase - maleta	6.95	6.96	30.60	4.80	0.00	1.15	1.39	8	6	1.15	913	667	657	691
Cheek - mejilla	5.75	6.39	41.68	5.95	1.95	1.43	1.44	5	7	1.26	888	685	652	681
Nun - monja	6.20	6.83	47.33	5.20	0.48	0.85	1.22	3	5	1.05	909	807	646	702
Sheep - oveja	6.40	6.83	38.40	5.35	1.38	1.63	0.78	5	5	1.00	1008	961	639	729
Iron - plancha	5.80	6.78	32.40	4.84	1.64	1.86	0.85	4	6	1.11	950	726	658	658
Health - salud	2.75	4.43	34.20	5.95	2.03	2.12	1.87	6	5	1.05	902	669	625	631
Fox - zorro	6.90	6.91	37.80	4.66	1.15	1.04	0.85	3	5	1.21	863	767	634	649
M	5.46	6.25	40.58	5.31	1.28	1.32	1.41	5.44	6.13	1.11	928	749	651	691
S	1.42	0.99	7.92	0.74	0.68	0.66	0.53	1.71	1.20	0.12	85	116	24	65

Note: Eng Imag = English imageability, Sp Imag = Spanish imageability, En AoA = English age of acquisition, Sp AoA = Spanish age of acquisition, En K & F = English Kucera and Francis (1967) word frequency count, En Fr Celex = English Celex frequency count, Sp Freq = Spanish word frequency, Eng L = English number of letters, Sp L = Spanish number of letters, Trans Accy = Translation accuracy, RT = Translation recognition reaction times.