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Words and bilingualism : neural and behavioural correlates of crosslinguistic influence in category structure

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Words and bilingualism: Neural and behavioural correlates of crosslinguistic influence in category structure.

Néstor Viñas Guasch

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Contents

List of abbreviations:

AC/PC – Anterior commissure – posterior commissure line
Ag-AgCl – Silver chloride
ANOVA - Analysis of variance
ATL - Anterior temporal lobe
EEG - Electro encephalogram
ERP - Event-related potentials
fMRI - Functional magnetic resonance imaging
Hz - Hertz
ICA - Independent component analysis
IIR –Infinite impulse response
Ms - Milliseconds
PET - Positron emission tomography
RFX – Random effects analysis
SD - semantic dementia
SOA – Stimulus onset asynchrony
TMS - Transcranial magnetic stimulation

Summary

The aim of the present thesis was to investigate the relationship of language and though by examining the process of categorisation and word meaning retrieval in bilingual and monolingual samples. The study of categories has been dominated by the notion that categories are conceptually independent of language. In the present thesis, we adopt the view that, given that the development of conceptual knowledge is parallel to linguistic development, categories are shaped by language in the process. In the present research, different types of categories were used. These category types ranged from those that were more conceptually homogeneous (less linguistically dependent) and those that were more linguistically dependent.

Four studies are reviewed in the present thesis. In the first study, participants were required to judge which pictures of objects corresponded to a certain category in two conditions, a "linguistic" condition where the name of the category was provided and a "non-linguistic" condition where no category name was available. In the second study, participants were tested on a conscious within-category semantic priming study using a lexical decision paradigm. The third study involved ERP measures of a delayed semantic decision task, again using different category types. Finally, the last study used fMRI to examine the neural correlates of different categories in a masked semantic priming task.

The results of these four studies provide evidence for the differentiation of the category types, and additionally, support the notion of cross-linguistic influence in category structure and lexical and semantic retrieval.

Chapter 1

Introduction

The world that surrounds us humans is complex: matter combines in a vast array of substances and beings, which can be present in different contexts and that relate in different ways. The human mind has limited memory and attentional resources, and cannot "absorb" all of the world's overwhelming complexity and details in a photographic-like representation. It follows, then, that the human mind needs a mechanism in order to make sense of reality. Categories allow us to economise our use of concepts (mental representations of things) by guiding us in our normal interaction with objects, providing expectations and potential actions, based on previous experiences with the category (for instance, two apples are never identical, yet we don't need to create a new category every time we encounter a new apple).

The process of categorisation is widely seen as one of the basic cognitive operations (higher mental activity) that support knowledge in the human mind (Barsalou, 2008), and the basis for our thought, perception, action and speech, and it takes place in all our sensory and perceptual domains (vision, smell, haptic experience) but also in thinking and talking about kinds of things, performing kinds of actions, experiencing kinds of feelings, creating kinds of objects and so forth (Rosch 1973).

Categorisation occurs automatically, and consequently, it is easy to assume that categories are built upon commonality, upon things of the same “kind”. The western philosophical tradition has long regarded categories as containers of entities that share common defining features. Under this doctrine - named the classical theory of categorisation (Medin & Smith, 1981; Murphy, 2002)- categories are disembodied entities that are independent from human existence. Furthermore, categorization has been viewed as an automatic and unproblematic process where categories are given to us humans from the ‘real world’, and that ultimately, categories become meaningful by referring to things that exist in the real world. The classical theory of categorisation passed undisputed from Aristotle’s time until the second half of the twentieth century (Lakoff, 1987).

The last century saw the emergence of alternative accounts on categorization: the works of Ludwig Wittgenstein in the 1950’s and prototype theory proposed by Eleanor Rosch in 1973 highlighted a series of inconsistencies with the classical view that ultimately led to its demise as a valid theory of categorisation and opened the field for study from cognitive semantics perspectives. The cognitive semantics approaches assume the notion of categories of things that result from conceptual knowledge in the mind. This conceptual knowledge is actively constructed through our human biological and social experience, rather than being disembodied and present in the real world.

A shift in the way categories are viewed has been seen as changing the basic nature of research in human conceptual knowledge. According to Lakoff (1987):

> To change the concept of category itself is to change our understanding of the world. At stake is our understanding of

> everything from what a biological species is to what a word is. The evidence we will be considering suggests a shift from classical categories to prototype-based categories defined by cognitive models. It is a change that implies other changes: changes in the concepts of truth, knowledge, meaning, rationality - even grammar-. (pg.9).

In fact, research on categories is linked to research in many other branches of cognitive science such as conceptual representation, developmental studies and psycholinguistics. There is developmental evidence of a strong correlation between language development and cognitive development (Bowerman, 1996, Levinson, 2001). Language is an essential component in the process of interaction between individuals and the wider culture from childhood**,** so that the use of words by children is often taken in developmental studies as an indicator of whether they possess or lack certain concepts; many times, learning a new word goes hand in hand with learning a new concept (Murphy, 2001).

Given the potential influence of language on conceptual knowledge and on more general cognitive processes, a lively debate has emerged around the nature of the relation between the medium in which we think and the medium in which we speak. The fact that language development and cognitive development happen at the same time suggests that thought and language might not be completely separate. Authors inspired by the Sapir-Whorf linguistic relativity hypothesis (Whorf, 1956) argue that the language that we speak determines the way we think and even affects the way we perceive things. On the other end of the spectrum, some authors argue that intelligent, elaborate thought can take place without language (Pinker, 1994). A more extensive discussion on the relationship between language and thought can be found in the second chapter.

Some scholars have proposed the existence of linguistically-mediated and non-linguistically mediated knowledge (Jarvis & Pavlenko, 2008): Linguistically mediated concepts are defined in cognitive psychology and language development literature as conceptual representations that, in the process of conceptual development, are shaped by distinctions and categories encoded in the language being learned, while non-linguistically mediated concepts are assumed to be unaffected by language.

A further dimension to the debate on the relationship between language and thought comes from the issue of whether we humans "think in the way we speak" (Pinker, 1994), or in other words, whether the representations that underlie semantic meaning are the same kind as the representations that underlie conceptual meaning (Levinson, 1997). In research on concepts using monolingual populations, it has long been assumed that there is a direct one-to-one mapping between semantic knowledge and conceptual knowledge (Jarvis & Pavlenko, 2008). However, the literature on linguistic typologies and on crosslinguistic variation suggests that different languages carve the cognitive space in different ways (Pavlenko, 1999, Levinson, 1997, Levinson, 1999), and it often occurs that words in one language have more than one translation equivalent in another language (Jarvis & Pavlenko, 2008), or that in some cases a language might have a lexicalised concept -a concept for which there is a word- where other languages do not have it, for instance, in Spanish there is no word for *seafood* (*marisco* in Spanish meaning "shellfish" but not "sea fish"). Effects of linguistic transfer are not exclusive to cross-linguistic effects of one language on another language (or a dialect on another dialect). For instance, the scope of a category can be influenced by the context (the category *tomato* will be considered as a vegetable in a culinary setting, but will be considered in a fruit from a scientific standpoint), but in the present research, the use of a late bilingual population is to explore effects of the L1 onto the L2.

In addition to cross-linguistic effects, there is evidence that formation of concepts in children is guided by the particular semantic organisation of the language they are learning (Gathercole & Moawad, 2010; Bowerman & Choi, 2003). Children who have not fully mastered the language they are learning make errors of over- and under-extension, for instance, grouping things in the same category when their language makes a distinction between the two. It is suggested that the errors children make in learning reflect properties of their general conceptual system (Murphy, 2001).

The study of categorisation in the human brain is linked with clinical psychology studies with brain damaged patients who present impairments in naming or recognising things from certain categories but not others (Stemmer & Whitaker, 2008) and also semantic dementia patients who have deficits in their general conceptual knowledge while their other cognitive functions are comparatively well preserved (Patterson et al., 2008). More recent research has used neuroimaging techniques to identify the localisation of brain regions associated with the representation of conceptual knowledge (called "semantic knowledge" or "semantic memory" in the neuroimaging literature, but not to be mistaken with the sense of "lexical semantics" or word meaning). According to

Martin (2001), word meaning is a "fairly intractable problem" (p.152), given the polysemic nature of words, and a way to circumvent this problem consists in limiting studies to concrete objects and the features that define them. Consistent with this view, studies have shown different patterns of neural activation for animals and tools (Martin, 2001) a dissociation which has been attributed to the fact that conceptual knowledge about animals consists primarily of visual attributes, while in the case of tools, this knowledge is predominantly about the way we use them.

Other authors provide category dissociation accounts based on evolutionary explanations, where the human conceptual system would have evolved to represent kinds of things that are relevant to survival, such as animate and inanimate objects, foods and man-made objects (Caramazza & Shelton, 1998). A different theory on conceptual organisation suggests that conceptual knowledge is grounded in the sensory systems (which are used for both perception and action). Under this assumption, thinking about an object involves the brain areas that were active during interaction with a given object (Barsalou, 2008). Finally, a more recent account proposes that abstract conceptual knowledge is integrated in a modality-independent hub that has connections with the different modalities (visual, olfactory, tactile).

Research in language and conceptual representation in bilinguals has focused on questions like whether the two lexical systems of a bilingual reside in different stores or whether they share a common system (Abutalebi & Green, 2007) and also on how lexical access occurs in the bilingual mind, where two (or more) potentially conflicting systems compete for activation (Dijkstra & Van

Heuven, 2002).

The goal of the present thesis is to examine the relationship between language and thought, that is, whether there are behavioural differences between the way speakers process linguistically and non-linguistically mediated knowledge and whether these two types of knowledge involve the use of common or separate neural processes. In this sense, the four studies presented in this thesis examined concepts that are lexicalised in Spanish but not in English (where there is a word for the concept in Spanish but no single equivalent word in English). Besides lexicalised (in Spanish) concepts, the studies used equivalent concepts that were not lexicalised in Spanish. In this way, the results of the studies could be taken as an indicator of different behavioural and neural processing of linguistically mediated and non-linguistically mediated knowledge. Additionally, linguistically-mediated concepts were divided into categories depending on the mechanisms that define category membership. These different category types are introduced in the next chapter.

The structure of the present thesis is as follows: the second chapter introduces the theoretical background of categorisation and research in the bilingual lexicon.

The third chapter focuses on the existing research in neuroscience on the conceptual and semantic organisation of knowledge in the brain.

Chapter four describes the stimuli that was used in the studies described in the experimental chapters.

The fifth chapter presents a category membership judgement study, where monolingual Spanish and bilingual Catalan-Spanish participants were required to make behavioural responses about the category membership of objects.

The sixth chapter describes a word priming study using a lexical decision paradigm, which used different types of categories, and that used English monolingual and Spanish-English bilingual participants.

The seventh chapter focuses on an ERP study that used an explicit semantic decision task with word pairs, again using monolingual English and bilingual Spanish-English speakers.

In the eighth chapter, a word priming study which used fMRI to examine potential differences in the neural substrate of different types of categories is described. As with chapters six and seven, participants were monolingual English and bilingual Spanish-English.

Finally, chapter nine summarizes the findings of all studies, and these results are discussed within the more general theoretical background to the study of categorisation.

Chapter 2

Language, Thought And The Meaning Of Words

2.1 Introduction

The relationship between the way in which we humans think and the way in which we speak has led to a lively debate in cognitive science. This debate is not about whether the message conveyed through language changes the content of what we think –whether by talking to each other we can influence what we think-, as it is obvious that this is the case- but instead, the debate focuses on whether the language we speak influences the way our thought is structured.

In the language and thought debate, authors at one end of the spectrum argue that humans possess a "language of thought" or "mentalese", which is already present before learning a language (Fodor, 1975; Pinker, 1997). Under this view, language is a cognitive module, separate from the general cognitive system, and intelligent thought can exist without language. At the other end of the spectrum, developmental studies have shown that language development in children runs parallel to general cognitive development, and therefore it is plausible to support the notion that language and thought influence each other (Levinson, 1997; Bloom & Keil, 2001). At the extreme end of the spectrum, the Sapir-Whorf hypothesis of linguistic relativity (1929, 1956) argues that language determines thought. In words of Benjamin Whorf: "We dissect nature along lines laid down by our native language. The categories and types that we isolate from the world of phenomena we do not find there because they stare every observer in the face; on the contrary, the world is presented in a kaleidoscope flux of impressions which has to be organized by our minds—and this means largely by the linguistic systems of our minds. We cut nature up, organize it into concepts, and ascribe significances as we do, largely because we are parties to an agreement to organize it in this way—an agreement that holds throughout our speech community and is codified in the patterns of our language [...]" (Whorf, 1956: pp. 212–214). Linguistic relativity is plausible in the sense that language might entice its speakers to draw attention to distinctions that they might otherwise not have noticed (i.e. Fingers and toes is a distinction that exists in English but not in French or Spanish. Murphy (2002) argues that stating that language determines thought is equivalent to saying that people cannot notice these distinctions unless they are present in the language (like saying that Spanish speakers cannot differentiate a finger from a toe because their language does not make that distinction). Besides being too strong a claim, the notion of absolute linguistic relativity has given rise to "folk theories" that take the existence of a large lexicon in one aspect as evidence of cognitive differences, such as the famous Eskimo snow hoax –the idea that Eskimos have N words for snow and therefore they must think differently-, historically, it is more likely that the activities (and surrounding environment) determine the vocabulary than vice versa, for instance, there are members of the English linguistic community who have many words for snow: skiers (Murphy, 2002).

Scholars that support the notion that language influences thought focus on different aspects of this effect. According to Bloom (2001), there are views that support language general effects -the effect of having a language on thought, compared to the effect of not having a language on thought (Vygotsky, 1962)-, or language specific effects –the effect of speaking language A on thought, compared to the effect of speaking language B on thought (Sapir, 1929; in Whorf, 1956). Additionally, different research has targeted the type of effect that language has on thought, such as perceptual effects (differences in the perceptual experience of speakers of different languages), effects in the structure of time, space or matter and also how language has an effect on the shaping of categories.

Categorisation takes place in all our sensory and perceptual domains (vision, smell, auditory and haptic sensation) but also in thinking and talking about kinds of things, performing kinds of actions, experiencing kinds of feelings, creating kinds of objects and so forth (Rosch & Mervis, 1975; Murphy, 2002). Categories allow us to economise our use of concepts by guiding us in our normal interaction with objects, providing expectations and potential actions, based on the previous experiences with the category (two apples are never identical, yet we don't need to create a new category every time we encounter a new apple). Category formation in children is part of the more general cognitive development and it occurs at the same time as language development. This fact suggests there is interplay between language and categories. As Murphy (2002) points out, the proper use of a word by a child is often taken as an indication that the child possesses a certain concept, and often, the term word and category can be used interchangeably. In order to clarify whether we are referring to a word or a category, in the present thesis, where the distinction between words and categories is needed, the typography of words will be italicized (i.e. *dog*) while categories will be capitalised (i.e. MAMMAL). Note that in this case, the term "category" denotes the class of a concept.

2.2 Categories and Word Meaning

Semantics is the branch of linguistics that examines meaning. In traditional semantics (also known as referential semantics), words receive their meaning by referring to 'real' objects or entities that are independent from human existence (see Russell, 1905). The widespread acceptance of referential semantics is motivated by the fact that this account makes it possible to verify the logical truth of statements. The truth of a statement such as "her car is red" is easy to verify, by examining the colour of the car in question. However, Murphy (2002) points out that referential semantics, while a valid linguistic theory, is not a valid psychological account for how words acquire their meaning or for how concepts are represented, and that for instance, to acquire the meaning of a word such as *dog*, one would have to know the set of all existing present, past and future dogs, which is clearly unfeasible. A more general psychological, but also philosophical theory on categories is the classical view. Under this doctrine, concepts are mentally represented by definitions (Murphy, 2002). Such definitions provide the features that are necessary and sufficient for category membership. Consequently, potential members of a certain category need to possess the set of necessary features. For instance, *cat* is a term that can make reference to Persian cats, Siamese cats, Norwegian forest cats or any other cats. What are the essential and necessary features of the word *cat*? It is possible to find a set of features that are shared amongst members of this category: [+animal], [+carnivorous], [+soft fur], [+short snout], [+retractile claws]. Things such as a bear which has features such as [long snout] and [non-retractile claws] instead of [short snout] and [retractile claws] do not qualify as *cats* since they do not possess all the features required to be included in the category. On the other hand, the set of features provided by the definition is sufficient in order to determine whether an entity is a category member or not, and in this particular case, any animals that have the set of necessary features ([+animal], [+carnivorous], [+soft fur], [+short snout], [+retractile claws]) have to be cats. One consequence of the classical view is that all things that possess the set of necessary and sufficient features are equally good members of the category (a Siamese cat is as good a cat as a lion). Additionally, the boundaries of categories are clear-cut and well defined: members fall either in or outside of the category depending on whether they possess the necessary features or not (an animal either is or is not a *cat*).

According to Lakoff (1987), the classical view is grounded on objectivism, a larger philosophical approach to knowledge and reason. Under the objectivistic doctrine, the relationship between concepts in the universe is ruled by Reason, a universal truth that is disembodied and thus transcends the human being and is present in symbolic logic or mathematics. Objectivism assumes the view that human thought is the manipulation of abstract concepts that represent things in the world.

The assumptions of the classical theory were largely unchallenged until Ludwig Wittgenstein outlined a series of problems with the classical view (Wittgenstein, 1953) and later when Eleanor Rosch proposed the prototype theory (Rosch, 1975).

Family Resemblance

Wittgenstein argued against the notion that categories can be defined with a necessary and sufficient set of features and also that categories have well defined boundaries. The category GAME illustrates these facts: Different games do not share any one common set of features. Some games are based on competitiveness or sport (racing), others are based on strategy (chess), skill (pool) or amusement (solitaire). All of them are considered to be games yet it is very difficult, if not impossible, to find a definition with a common list of necessary and sufficient features. In fact, it is very difficult to find a set of necessary and sufficient features for most categories, and incidentally, the definition of even a word like *cat* as equivalent to = [+animal], [+carnivorous], [+soft fur], [+short snout], [+retractile claws] is not complete. Some *cats* that have no fur (such as the sphinx cat breed), and *cats* that for any reason (such as illness or an accident) may have lost the ability to retract their claws, are still considered *cats*. Furthermore, [+animal], [+carnivorous], [+soft fur], [+short snout], [+retractile claws] does not only define cats: A fossa -an endemic mammal of Madagascar, which is not classed as a cat- also fits that definition. Wittgenstein also noted that category boundaries are not well defined, and can, for instance, be extended or reduced at will. Depending on the situation a category such as NUMBERS can be considered to include positive numbers only (for example when asking somebody to guess the number of fingers that I am going to show in one hand) but it can be extended to negative numbers in other situations (when someone says that the temperature has dropped to -20 degrees Celsius).

Finally, the assumption that members of a category are equally good representatives of their category is often violated: in the category NUMBER, certain members are more central (better representatives of the category) than others. This is the case with positive numbers. When asking someone to think of a number, chances are that the number will be a positive rather than a negative number or a fraction.

The Prototype Theory

As noted by Lakoff (1987), Eleanor Rosch (1975) developed the prototype theory, which challenged the classical notion that category members have an equal status. Based on empirical findings, Rosch argued that categories have internal structure that causes certain members to be prototypical and others to be non-prototypical. Humans tend to be faster at identifying and making judgments about prototypical than non-prototypical members of categories. For instance, most people will agree that a robin is a more prototypical exemplar of the category birds than an ostrich, or that an apple is a more prototypical fruit than a pomegranate. Within the theory of prototypes, Rosch developed the concept of basic level categories. Basic categories stand at an intermediate level below superordinate and above subordinate categories. For instance, a basic category such as CAR stands at an intermediate level, below the superordinate category VEHICLE and above the subordinate category FORD. According to Rosch, basic level categories are the most informative, easiest to remember, and first to appear in the cognitive development of the child. For instance, a child will learn what a DOG is before learning that it belongs to the category MAMMALS (superordinate) and that it is of the breed POODLE (subordinate). Members of subordinate level categories share a higher number of features between them than do those in basic and superordinate levels (Rosch, 1975).

Cognitive Semantics Views on Word Meaning

The first real challenge to the classical view on word meaning, conceptual representation and categorisation came from the cognitive semantics approach. As mentioned earlier, the objectivist doctrine assumes that words acquire their meaning from the real world, which makes it possible to evaluate the logical truth of linguistic expressions. Instead, the cognitive semantics approach argues that word meaning derives from conceptual representations that reside in the human mind, rather that in the real world. It follows, then, that the logical truth of linguistic expressions is no longer essential in order to determine word meaning.

Conceptual Representations and Word Meaning

According to Gärdenfors (1996), conceptual representations –which are connected to word meaning- result from human perceptual experience and through interaction with the environment. Lakoff (1987) argues that word meaning is embodied, rather than existing in the real world. Embodiment implies that concepts are constructed and modified partly through perception and partly through interaction of our human bodies with the physical world. More specifically, Lakoff argues the fundamental element in human perceptual experience is spatial perception. Conceptual representations are based on image schemas, which reflect a spatial structure, such as containment (A is part of B) or source-path-goal (Lakoff, 1987; Gallese & Lakoff, 2005).

Language Variation.

The notion of word meaning as a function of perceptual experience partly explains differences in word meaning in different linguistic communities. For instance, several authors suggest that industrialised societies have more words for focal colours (Berlin & Kay, 1969). However, there are differences in word meaning between linguistic communities that share the same geographical territory, for instance, the word *glas* in Welsh corresponds to both *green* and *blue* in English. Perceptual experience does not explain why languages use words that do not apply any more (i.e. Latin American Spanish *carro* = *car*, which also has the meaning of " cart drawn by horses", even in predominantly urban settings where horse drawn carts are rarely used) or why word meaning is constantly evolving (the meaning of the word *gay* in the nineteenth century was "happy" or "carefree", whereas the predominant meaning today is "homosexual male"). To explain these phenomena, it has been argued that word meaning is also embedded in a more general knowledge structure unique to each linguistic community or culture (Lakoff, 1987, Pavlenko, 1999). Under this assumption, words obtain their meanings from reference frames. For instance, the word *bachelor* can only exist in cultures where males that reach a certain age are expected to marry or to stay single. The concept of bachelor cannot be applied to a religious context where males do not marry, or to a polygamous society (Lakoff, 1987).

Extensions: Words with Multiple Meanings

A consequence of the fact that categories are a result of the human interaction with the physical world (embodiment) and with culture (embedment) is that categories and the meaning of words can be extended with new meanings. This process is unique in each language and linguistic community (Lakoff, 1987). As a result of these extensions in meaning, most words are polysemous. Two main types of words with multiple meanings can be distinguished: homonyms and categories with a radial structure.

Homonyms are ambiguous word forms, in the sense that the same word form encompasses different meanings that are not related. One example of homonyms is *bat*, a nocturnal mammal capable of flying, and *bat*, a club that is usually made of wood, that is used for hitting a ball in sports like baseball or cricket. The senses of *bat* in the sense of a mammal and *bat* in the sense of a wooden club are completely unrelated meanings that have come to be accidentally designated by the same word form at some point through the history of the English language. Another type of polysemy that is relevant to the present research is the kind shown in categories that have a radial structure.

Semantic Ambiguity

The semantic processing of ambiguous words has been the subject of study in the last decades. Three traditional models can be noted: first, context dependent models, second the context independent single access models and third, the multiple access or exhaustive model (which is also context independent).

The context dependent models (Schvaneveldt, Meyer and Becker, 1976; Simpson, 1981) presuppose that the context of the sentence determines which meaning of the ambiguous word is activated, for instance, when the context favours the activation of a meaning of an ambiguous word. For instance, by using the prime money preceding the ambiguous word "bank", Schvaneveldt et al., found that a target related to the activated meaning ("save") was processed faster than a neutral target, but no facilitation was found for a target related to the other, non-activated meaning ("river").

On the other hand, the Single Access or Ordered-Access model (Hogaboam & Perfetti, 1975; Forster, 1976) assumes that context does not influence meaning retrieval: All meanings are retrieved sequentially, and the order in this sequence is determined by the frequency of the meaning (higher frequency meanings are retrieved earlier).

In the Multiple Access Model or Exhaustive Access Model (Holley-Wilcox & Blank, 1980), the authors argue that all word meanings are retrieved automatically and simultaneously upon presentation of an ambiguous word. Several variations to the Multiple/Exhaustive Access Model have been proposed: Onifer & Swinney present a model where all word meanings are accessed in parallel, and context affects the meaning-selection process, while Seidenberg (1982) argued that the speed of activation of ambiguous word meanings is a function of their frequency.

The multiple/Exhaustive access model has been the most widespread in the past, given that it assumes that the lexicon is a separate, autonomous module.

Additionally, this model is most suited to the present research, given that the present studies aim at examining context-free L1 meaning activation in tasks using the L2.

Despite the popularity of the Multiple/Exhaustive Access model, recent research has revived the issue of the influence of the linguistic context on the retrieval of word meaning. In particular, Elman (2011) found that the grammatical structure of sentences determines to a certain extent, the selection of word meaning. In particular, verbs were shown to have a preference for thematic roles and word fillers. For instance, "Shrewd, heartless gambler" is a better agent for the verb "manipulate" than "naïve young gambler", which is, in turn, a better patient for the verb "manipulate". Additionally, the sentence "the cop arrested…." Promotes a Main Verb reading over a Reduced Relative interpretation, (i.e. providing information about "what" the cop arrested). In this case We would expect the sentence to continue like "the cop arrested…a thief". On the other hand, a sentence like "the thief arrested…" promotes a Reduced Relative interpretation, (i.e. providing more information about the thief) so we would expect the sentence to continue like "the thief arrested had been in the area for five days".

Elman (2009, 2011) challenges the notion of the lexicon as a separate, modular store and calls for a revision of theories on what constitutes the lexicon. However, the specific nature of the lexicon falls outside of the scope of the present thesis.

Radial categories and the lexicon

The notion of radial categories is a radical departure from the classical view in which categories are built upon common features. Instead, radial categories have multiple senses: a central, predominant application and peripheral, conventionalised extensions of the central use. A case that exhibits the aforementioned radial structure is *leg*, as it is used in the English-speaking community. *Leg* refers centrally to the concept of LEG as part of the body (limb) that allows humans and animals to walk or to stand. This use of *leg* as "a part that sustains a body" extends through a metaphorical process to the parts that sustain not only living bodies, but also, e.g. chairs or tables. Radial links are motivated in that we can understand why a category has been extended with a particular meaning, in this case, we can understand what mechanism (analogy) produced the extension of the word *leg* (human body part) to denote a structural part of a chair.

Children who are learning their native tongue acquire the extended meanings in radial categories through interaction with a particular physical and social world, and as a consequence, these extended meanings are specific to each language and each linguistic community and cannot be predicted from the central meaning (Lakoff, 1987).

Another example of a category that presents a radial structure is *tea* (from Gathercole, in preparation). The central meaning of the word *tea* is restricted to the drink made by infusing the dried leaves of the tea plant (although the original form of the word *tea* might have referred to the plant itself, but in a language other than English). However, in Great Britain the drink is commonly included in a light meal in the afternoon, and even the cooked meal that is served in the evening. In this case, the two meals (in the afternoon and in the evening) have come to be referred to as *tea* ("She's having soup for tea today") by thematic association, even if in many circumstances, tea is not served in conjunction with the meal. This process of extension of meaning has been called chaining (Lakoff 1987). Chaining takes place when a word with a certain use might be extended to a related kind of thing, this new use can be extended to something that is related to that, and so on, so that with enough 'links', the senses end up being very different. Malt et al. (1999) argued that chaining occurs also when existing words are used to name new objects. For instance, when juice containers first appeared in stores, they were a variation on boxes (square shaped, made of cardboard), and thus they were named "juice boxes". The word "juice box" has continued to be used in this sense, even though many juice containers come in many different shapes and materials, and some resemble bottles more than boxes. Other mechanisms responsible for the extension of a central meaning to other senses are imagination processes (Lakoff, 1987) such as metaphor ("He *fell* into his trap"), metonymy ("There were three hundred *souls*") and visual schemata ("the *tip* of the iceberg" and "the *tip* of the pen") or using the name of a tool to talk about the action of using the tool ('*penned* a letter to her mother').

The radial structure of categories raises a question regarding the conceptual representation of word meaning. Some scholars argue that the different senses of radial categories reflect a common 'core' meaning that is found in all uses of the word (Ruhl, 1989). However, there are many arguments that disprove the notion of a 'core' meaning. First, as noted above, categories are not necessarily built upon commonality, and second, finding the core meaning of some words is very difficult, it not impossible, and often context dependent (i.e. *chicken* in the sense of a domestic fowl and in the sense of meat of said domestic fowl as food). It follows then, that radial category meaning is not based on a single core concept, but that words draw on a number of concepts to acquire their meaning.

The fact that quite often, lexical entries are connected to a number of concepts opens the question of how the different meanings of words are linked to the conceptual system, and most interestingly, how this connection occurs in a bilingual lexicon.

Most theories of language agree that lexical knowledge is stored in the lexicon. The lexicon is assumed to be a store of items that have long-term memory associations of formal (orthography, phonology, morphology) and semantic features (syntax and semantics) (Jackendoff, 2002; Jiang, 2000). The exact nature of the entries in the lexicon is debated. Some authors have likened the entries in the lexicon to the entries of a dictionary (Jackendoff, 2002; Katz & Fodor, 1963), while conceptual knowledge is "encyclopedic". This view contrasts with the position of other researchers who consider entries in the lexicon to include more information than just words, for instance, items that are smaller than words, like affixes that are derivational (/t/ - [PAST]) (Juffs, 2009), and authors who argue that knowledge in the lexicon is larger than words. Along these lines, Elman (2011) argues that words never appear in isolation, but instead, contextual information is always available. In the present thesis, the term lexicon will be used to designate lexical knowledge.

In research about the lexicon, a number of authors use the term “lexeme” to specify morphological, orthographic and phonologic properties of the word and the term “lemma” to specify semantic and syntactic properties (Kemper & Huijbers, 1983, Levelt, 1989), see figure 2.1. In this view, the lemma level of a word is separate from the more general conceptual store, which implies that there is a distinction between semantic and conceptual levels of representation. Under this assumption, knowledge at the semantic level involves implicit knowledge of links between lemmas and concepts or links between lemmas and other lemmas (i.e. word association, synonymy, or antonomy) (Jarvis & Pavlenko, 2010).

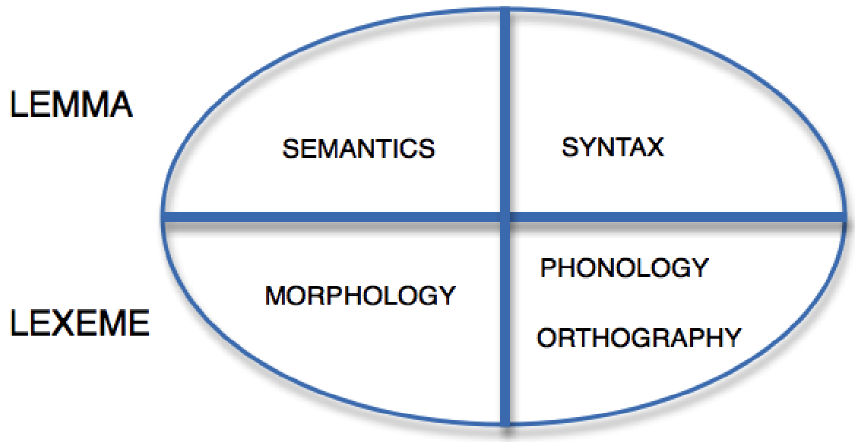


Figure 2.1. Structure of a lexical entry (adapted from Levelt, 1989)

On the other hand, knowledge at the conceptual level involves experiential and multimodal (mental imagery, sound, and so forth) representation of more general thought, such as the knowledge of properties of categories, information about prototypical, borderline, fuzzy and peripheral members of the category (Jiang, 2000) and knowledge of the internal structure of categories, and links to other categories (Malt, 1993; Murphy, 2002).

Murphy (2002) suggests that lexical entries are not necessarily mapped onto single concepts. Instead, it is argued that meaning is made of parts of conceptual structure, where words with more than one meaning are connected to parts of the conceptual store. Additionally, in both conceptual and semantic knowledge, there is a distinction between implicit knowledge: knowledge that the individuals may not be aware of but which researchers can infer from their systematic verbal performance and explicit knowledge –which involves word definition and grammar rules that individuals are capable of verbalizing on demand (Paradis, 2004)-

While the notion that semantic and conceptual knowledge are separate is common in studies with bilingual populations, it must be noted that most studies in psycholinguistics and models of the mental lexicon rarely differentiate between conceptual and semantic levels of representation (Barsalou, 2003). Instead, the term "semantics" is used interchangeably to refer to a semantic and conceptual system (Francis, 2005). Some authors have argued that in the monolingual lexicon there is direct one-to-one mapping between semantic knowledge and lexicalised knowledge (Jarvis & Pavlenko, 2009), and therefore, studies examining the monolingual lexicon do not need to differentiate between the semantic and conceptual levels of representation. However, there is empirical evidence in psycholinguistic and neurolinguistic studies supporting the distinction between semantic and conceptual levels of representation (Paradis, 1997), and studies in clinical neuropsychology have shown that patients with anomia and aphasia exhibit impaired semantic knowledge while their conceptual knowledge is not affected (Lecours & Joanette, 1980).

In contrast to studies using monolingual populations, most studies on the bilingual lexicon aims to understand the relationship between the two languages in the mind of a single speaker, and therefore require careful differentiation between semantic and conceptual levels of representation: it could be, for instance, that the two languages present differences in the structure of particular conceptual categories, or in the links between these concepts and words, as well as between words and other words (a *cup* in English can mean *a cup* or a *mug* in Spanish), or it could be that the languages differ only at the semantic level, but not at the conceptual level (*fingers* and *toes* in English, and *dedos* in Spanish are likely conceptually identical), and additionally, it could be that bilingual semantic and conceptual structures are different from their monolingual counterparts. Some authors suggest that the relation between the two lexicons of a bilingual speaker is modulated by proficiency, frequency of use of each and lexical similarity of the two languages (Kroll et al., 2005). In particular, two findings are especially interesting: differences in reaction times in translating from one language to the other, differences in reaction times in translating cognates, compared to non-cognates, and concrete words, compared to abstract words. Different models have tried to accommodate for these findings in the bilingual lexicon: The Revised Hierarchical Model (Kroll & Stewart, 1994) intends to explain a phenomenon found in translation between the bilinguals' two languages: translating a word from L2 to L1 is faster than translating from the L1 to the L2, and translation from L1 to L2 is faster than picture naming in the L2.

The Revised Hierarchical Model (RHM) posits that in novice L2 learners, L2 lexical entries are more strongly linked to their L1 translations than to concepts, and thus L2 picture naming hypothetically activates concepts, then L1 lexical entries and then L2 lexical entries. L2 to L1 is faster because the L2 to L1 links are stronger than the L1 to L2 links (see figure 2.2).

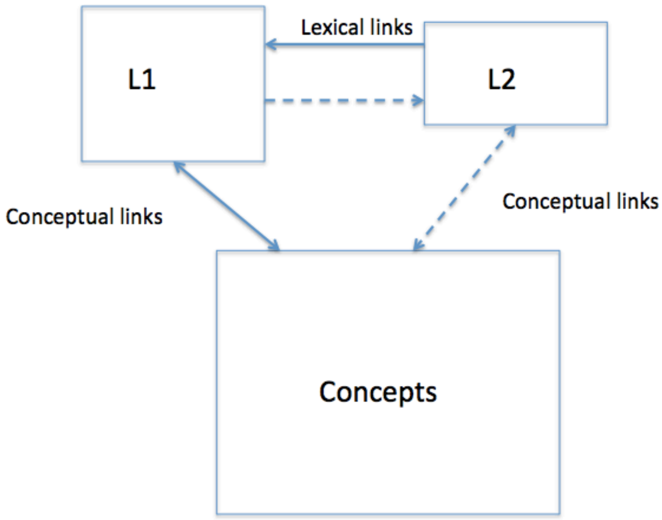


Figure 2.2. Revised hierarchical model (Kroll and Stewart, 1994)

Jiang (2000) elaborates on the RHM, by proposing a three stage developmental model of lexical entries in the L2. In the first stage –called the L1 mediation stage- L2 lexical entries are essentially "form" entities, without semantic content. In this stage, meaning of L2 lexical entries is mediated by accessing L1 entries (lemmas). In this case, recognition of an L2 word implies access to the L1 translation equivalent (there is also access to information about the L2 word, such as a formal definition learned in instructional settings, but this information resides in the general, episodic memory system and is not an integrative part of the lexical entry itself). As learners become more proficient in the language, L2 and L1 links strengthen, so that L2 word and its L1 lemma translation become attached, or where the L1 lemma translation is copied onto the L2. This stage is known as the L1 mediation stage, and implies that activation of L2 word forms involves activation of the L1 lemma information (and possibly of the L1 word form as well, though this is not as clear). However, links between L2 lexical entries and concepts are still weak at this stage.

A final stage is reached when L2 lexical entries are complete, having morphological, syntactic and semantic specifications, in a similar way to the L1 lexical entries. However, it is common that speakers' lexical entries "fossilize" in the second –L1 lemma mediated- stage (see Jiang, 2000 for a discussion of this phenomenon).

The RHM has several shortcomings: one of the major problems is that it only addresses concepts that are fully equivalent between languages, or in other words, concepts where L1 and L2 share the same category structure and boundaries (Pavlenko, 2009). Additionally, the RHM does not address cases where concepts are not equivalent, and this poses a serious limitation, since semantic organisation shows a great degree of variety across languages and cross-linguistic comparisons can yield valuable information about the relation between the semantic and conceptual systems. For instance, some languages might have a lexicalised concept where others do not. In the Dyirbal language, *balam* denotes edible fruit and plants that bear them, tubers, ferns, honey, cigarettes, wine and cake. English does not have such a term, but uses different words for all of the foods aforementioned (Lakoff, 1987). It can also be the case that a term exists in both languages, but the "range of application" differs between languages. For instance, English has the verbs *to dry* and *to wipe* where the Swedish equivalent, *att torka* has a broader range of application because it refers to both *to wipe* and *to dry.* Along the same lines, the English noun *handle* has two Spanish equivalents: *mango* (i.e. handle of a pan) and *pomo* (door handle). Moreover, concepts in one language often do not “align” with their equivalents in another language. Rather than just being a subset or a superset of the concept in the other language, concepts can have multiple overlapping relations (Gathercole & Moawad, 2010). The English preposition *for* corresponds to the Spanish *para* and *por* but *por* also corresponds to *by (*agent), *through*, and *because of*. English *by* corresponds to *por* but also *al lado de (“*beside*”)* and so forth (Gathercole & Moawad 2010).

A different model of the bilingual lexicon that does address concepts that are partially equivalent, or non-equivalent between languages is the Distributed Feature Model (DFM) proposed by De Groot (1992), see figure 2.3**.** The DFM takes into account the phenomenon that cognate and concrete nouns are translated faster than abstract nouns in bilinguals. The DFM assumes that representation of cognates and concrete nouns are largely similar across languages, while abstract and non-cognate words are separate (De Groot, 1992). However, while this model provides an explanation for how non-equivalent and partially equivalent categories, it does not provide a developmental account of L2 lexical entries (Pavlenko, 2009).

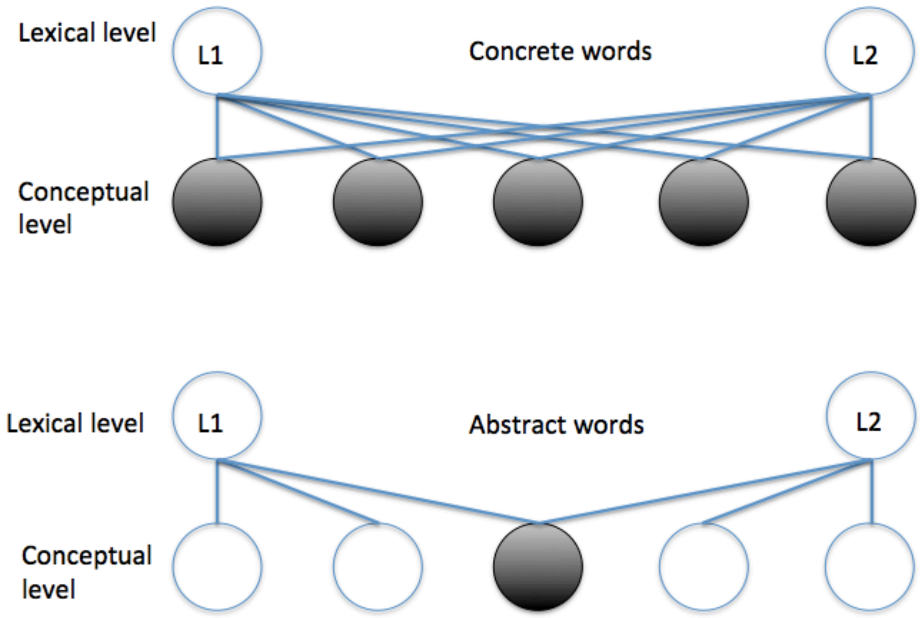


Figure 2.3. Distributed feature model (Van hell and De Groot, 1998)

In order to solve the shortcoming of both the revised hierarchical model and the distributed feature model, Pavlenko (2009) proposed the Modified Hierarchical Model (MHM). The most prominent feature of the MHM is that it assumes a conceptual store formed by L1 specific categories, L2 specific categories and categories that are shared both by the L1 and the L2 (see figure 2.4).

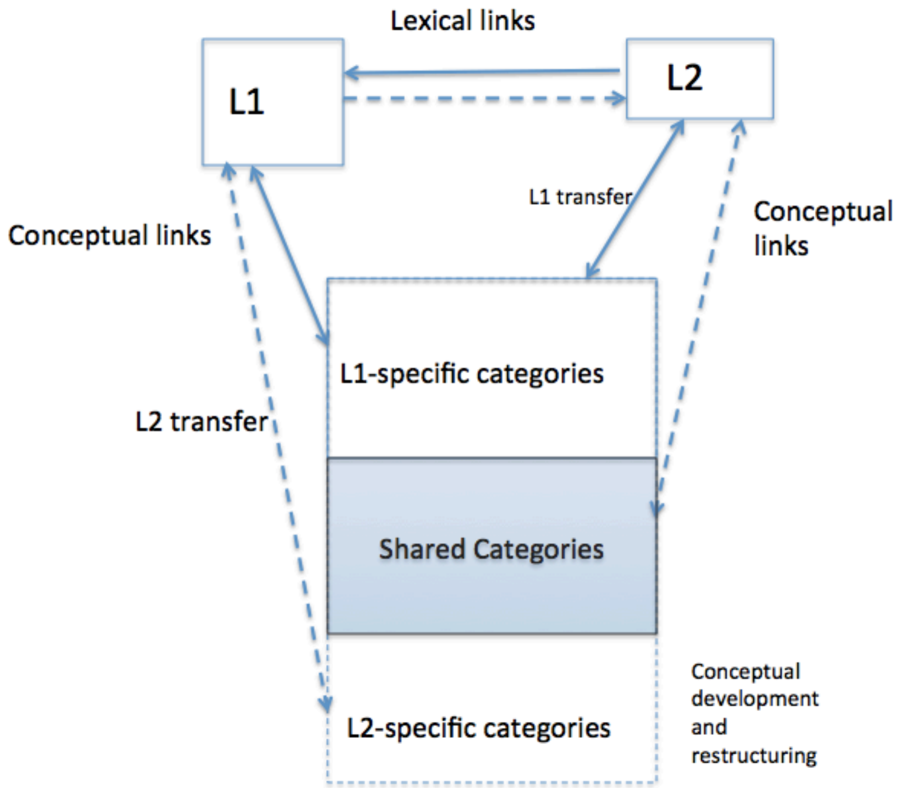


Figure 2.4. Modified hierarchical model (Pavlenko, 2009)

An especially relevant feature of the MHM to the present thesis is that it explains the phenomenon of conceptual transfer. Pavlenko (2009) argues that semantic information is specified in terms of links between words, or links between words and the conceptual system. It follows then, that under the MHM, it is possible to distinguish between errors due to conceptual transfer (errors in the structure of categories). For instance, a native Spanish speaker who is an L2 speaker of English might say '*fingers of the foot*' to refer to *toes*, which is an error cause by the speaker using the Spanish category boundary of FINGER, which encompasses fingers and toes, instead of the English separate categories, for fingers and toes. Conversely, an error of semantic transfer would be a Finnish speaker who said “he bit himself in the language” (Ringbom, 2001) to mean that he bit himself in the tongue. The Finnish word *kieli* translates into English as *tongue* and *language.* And the error that the speaker made was to apply the semantic structure of *kieli* and choose the higher frequency word *language* to refer to tongue (body part).

Recent studies suggest that not only does L1 have an effect on L2, but L2 also affects L1. Pavlenko (2004) note the case of a Russian L2 speaker of English who applied the adjective *unhappy* (Russia: *schastlivaia*) in the English sense of “temporally dissatisfied”. However, the Russian word *schastlivaia* makes reference to a permanent state of unhappiness.

The notion that words are connected to larger conceptual structures raises the question of how different speakers, who might have a different perceptual experience –even within the same linguistic community-, succeed in converging in which subsets of the larger conceptual structure constitute the meanings of a word. Clark (1996) argues that there is a social component of language and word meaning: word meaning is shaped by the interaction with other speakers of the same language, and if this is the case, then we can argue that social constraints on word meaning then also determine category boundaries, and the fact that this socialisation process happens within linguistic communities (and not between them) partially explains why category systems and word meanings are so different between languages, and also between linguistic communities that exist in the same geographical area (and should therefore have a similar perceptual experience).

A question that is related to the process of assigning a subset of a conceptual representation to word meaning is whether the inverse process happens: does word meaning have any effect on conceptual representations? In this sense, we can make a distinction between language independent and language dependent concepts. Mental representations of language independent concepts develop experientially and have no predetermined means of linguistic expression (Juffs, 2009). On the other hand, cognitive psychology defines language mediated (or dependent) concepts as conceptual representations that have developed to reflect language-specific lexical and grammatical categories. Murphy (2002) argues that language mediated concepts develop in the process of language socialisation. In this case, word learning and category acquisition influence each other in the process of cognitive development: word meaning changes to reflect conceptual structure, but also, word learning shapes conceptual structure. Summarizing, conceptual development interacts with distinctions and categories that are present in the culture and linguistic community of the child, in a process that promotes distinctions that are particular to the language being learned. For instance, English and Korean differ in their concept of *fitting.* English makes a distinction between containment relations and support relations (*in* and *on* respectively). On the other hand, Korean does not make such a distinction, but instead it distinguishes between tight-fitting relations (*kkita*) and loose-fitting relations (*nehta*) (Bowerman & Choi, 2001).

Language mediated concepts can be divided into lexicalized concepts - concepts connected to words such as “finger” or “car”- and grammatisised concepts, which are linked to morphosyntactic categories, such as number, gender or aspect (Murphy, 2002).

Given that the boundaries of categories differ from one language to another but perception of features is shared across cultures (Pavlenko, 2000), it is especially relevant to study whether bilinguals' category boundaries differ from those of monolinguals. Such a question is motivated by the fact that bilingual and second language speakers have to either maintain two sets of boundaries (one for each language) or a shared set of boundaries that merges category boundaries from both languages (Ameel et al, 2005).

Research in developmental psychology suggests that acquiring category boundaries is not a trivial task. As Gathercole (2010) points out, even monolingual children make errors of over- and under extension when learning the category system of their language (Bowerman, 1996) and L2 speakers never attain the same accuracy determining category boundaries as native speakers (Malt & Sloman, 2003). Additionally, there is evidence that bilinguals' two category systems are vulnerable to "convergence", that is, bilinguals' two naming patterns converge into a common naming pattern. (Ameel et al., 2009). Ameel & collaborators (2009) performed a comparison between the category boundaries of French and Dutch monolinguals and those of Dutch/French bilinguals and also a comparison of their ratings for typicality of category centers. It was revealed that the ratings for category centers of the bilinguals correlated more strongly than those of either the French or Dutch monolinguals. Bilinguals' category boundaries were simplified and less dependent on language conventions that monolinguals' category boundaries.

Semantic Priming

The semantic priming effect is described in the literature as the phenomenon that occurs when the response to a target word is faster and more accurate when this word is presented after a semantically related prime, than when it is presented after a neutral prime (Meyer & Schvaneveldt, 1971). For instance, response to the target word "CHAIR" is faster when the word is preceded by the semantically related prime "TABLE" than when it is preceded by the neutral prime "MOUNTAIN".

The semantic priming effect has been extensively used in research on word recognition (Andrews, 2008), reading (Hagoort et al, 2004; Dijkstra & Van Heuven, 2002), and most relevant to the present study, semantic priming has been taken as an indicator of conceptual organisation (Perraudin & Monoud, 2009). In the present thesis, semantic priming was used in three studies: Chapter six (semantic priming study) and chapter seven (fMRI study) used a lexical decision task, and chapter eight (ERP study) used a semantic decision task.

Lexical decision tasks

In lexical decision tasks, participants are required to decide whether a string of letters is a real word ("stencil") or not ("nilfer"). However, there are several variations to the lexical decision task. One of such variations is the sequential lexical decision task, where primes and targets are presented sequentially, and participants are required to make a response to each word. On the other hand, in the standard lexical decision task, primes and target are also presented sequentially, but participants only respond to the target word. In the present thesis, a sequential lexical decision task was used in chapter 6, and a standard lexical decision task was used in chapter seven.

Several parameters are critical when designing a lexical decision task. First is the duration of the prime, which influences whether the prime word can be processed consciously (in durations of more than 30 ms.) or unconsciously (durations of less than 30 ms.). Equally important is the SOA (stimulus onset asynchrony), which is the period of time elapsed between the presentation of the prime and the presentation of the target. Longer SOAs allow more time for the prime to be processed, thus increasing the likelihood that the prime word might prospectively activate the target word.

An additional parameter is the relatedness proportion, which is the percentage of prime-target trials that are semantically related. The relatedness proportion determines whether the semantic priming effect appears automatically or is subject to strategic control by the participant. If the effect is subject to participant strategic control, the priming effect will be shown in conditions where the semantic relatedness is high, and will be attenuated in conditions where the semantic relatedness proportion is low.

Other very important parameters concern the use of non-words: one such parameter is the percentage of trials where the target is a non-word (non-word ratio), as a higher percentage of non-words can bias participants towards responding that a letter string is not a real word, while low percentages might bias participants towards "yes" responses. Additionally, an increased ratio of non-words, relative to words, has been shown to influence performance on high and low dominance words (Neely, 1991) and to favour the use of semantic matching strategies (Neely, Keefe & Ross, 1989). Finally, non-words are pronounceable (pronounceable non-words are assumed to be processed more deeply than non-pronounceable non-words (Jones & Estes, 2012).

Semantic decision tasks

The study described in chapter eight examined semantic priming in conjunction with a semantic decision task. A semantic decision task requires participants to make a judgement on certain feature of the prime – target word pairs. For instance, participants could be asked whether both prime and target items are members of the same category. In this case response to the target-prime pair "CHAIR-TABLE" would be "yes", while the response to "DOG-PHONE" would be "no". In contrast to lexical decision, the semantic decision task requires participants to pay more attention to a certain semantic feature of the object (e.g. size, animacy, concreteness). It is hypothesized that the activation of the semantic representation is increased (as opposed to increased activation of the lexical representation in the LDT), thus enabling priming to be present at long SOAs (Becker et al., 1997).

Theories on semantic priming

Theories of semantic priming can be classified according to two criteria: first, whether priming is automatic or controllable (i.e. subject to strategic control), and whether priming occurs prospectively (i.e. the prime word pre-activates the target word) or retrospectively (i.e. prime and target words are evaluated together, and if they are congruent, response to the target is faster). Given this classification, we can distinguish between the Spreading of activation theory (automatic and prospective), the Expectancy theory (controllable and prospective), and the Semantic Matching theory (controllable and retrospective).

The Spreading Of Activation Theory

The spreading of activation theory (Collins & Quillian, 1969; Collins & Loftus, 1975) posits that concepts are stored as the nodes of a semantic network, and properties of a concept are represented as links between nodes. Additionally, the semantic network is organised in function of semantic similarity. The more related two concepts are, the more links there are between them, and the closed these concepts are to each other in the semantic network (see figure 2.5).

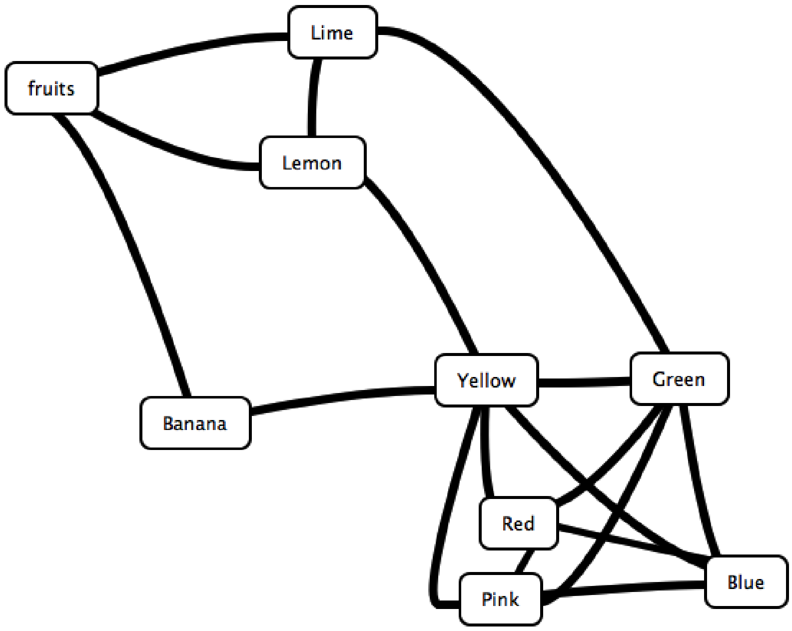


Figure 2.5. example of a possible semantic network.

When a semantic representation is activated, the activation spreads rapidly to the neighbouring nodes, which represent related concepts. The activation decreases as it progresses further into the network, so that the representations of related concepts present a higher degree of activation than the representations of unrelated concepts. Hence, activation is automatic and prospective: the node corresponding to the semantic representation of the prime is activated, and this activation spreads through the rest of the network, activating the semantic representation of the target word.

Expectancy

The expectancy theory hypothesises that when processing a prime, a list of possible targets is created. This is known as the "expectancy set". The relations between the prime word and the words in the expectancy set depends on the task used (e.g. if the task involves a prime and a target that is the antonym of the prime, the expectancy set will be constituted by words that can be the antonym of the prime). Words with few strongly related targets (i.e. WHITE ---> BLACK) generate a smaller expectancy set. Several authors have hypothesised that the generation of an expectancy set is a controlled process (Hutchinson, 2002) and prospective, given that the potential target is already activated before it is presented (Neely, 1991).

Semantic Matching

Semantic matching makes reference to the phenomenon of searching for a meaningful relationship between prime and target after both have been presented (Neely, 1977; Neely, Keefe & Ross, 1989). In a lexical decision task, participants can be guided by the fact that both prime and target are related, to respond that the target must be a real word. Conversely, participants might be biased to respond that a target is a non-word if it is not related to the prime. In this case, Semantic matching is a retrospective process (Occurs when prime and target have been presented), and it is a controlled process, affected by the relatedness and the non-word proportion.

Chapter 3

The Neuroscience Of Language

3.1 Introduction

The previous chapter introduced the theoretical background to the study of categorisation in the bilingual lexicon. The present chapter introduces the background of the study of conceptual and semantic representation in the brain in neuroscience. However, given that neuroscientific literature on the bilingual lexicon is scarce, most of the research reviewed here, with some exceptions, examines the conceptual representation and semantic processing from a monolingual perspective.

3.2 The Relationship Between Psycholinguistics and Neuroscience

The interrelation between psycholinguistics and neuroscience is a complex one. Traditional research in the language and brain uses neuroscientific methods to verify models proposed in cognitive science. While some authors argue that a collaboration between the language sciences and the neurosciences "should not be a one-way street with neuroscientists proving theories devised by language scientists" (Grosjean et al, 2003, p.161-162), other authors argue that models in cognitive psychology are based on decades of research ad should guide research in neuroscience, and that without these models, "the cognitive neuroscientist does not know what to look for in the brain" (Pylkkännen et al, 2011, p.1) and that there is no reason for neuroscientists to "reinvent the cogs of cognitive science" (Dijkstra & Van Heuven, 2006, p.192). Thus the relationship between the language sciences and the neurosciences seems to be open to question. In the present research, we will avoid entering the debate on the relationship between the cognitive science and neuroscience, there is an issue - needing clarification- that concerns the present research: the use of the word "semantics". The word "semantics" as used in neuroscience originates from the study of memory, while "semantics" in linguistics makes reference to lexical semantics.

Endel Tulving (1972) first made the distinction between semantic memory (general knowledge about objects, people, word meanings or facts, like knowing that giraffes live in Africa) and episodic memory (knowledge and recollection of past experiences, like remembering last years Christmas party). The notion of "semantics" as general knowledge has come to be widely used in neuroscience, and it has been adopted to refer in many cases the representation of conceptual knowledge (Thompson-Schill, 2003). As a result, research in neuroscience is mainly concerned with research questions such as the localisation of man-made versus natural things, tools versus faces, living versus non-living and so forth (Martin & Caramazza, 2003). The previous chapter introduced semantics as the "meaning" component of a lexical entry, or alternatively as "word meaning", separate from more general, conceptual knowledge. In the view of Pylkkännen et al. (2011), the difference in the senses of the term "semantics" is due to the fact that neuroscientific literature on conceptual representation is disconnected from linguistics. The present thesis is mostly concerned with how word meaning is connected with conceptual, non-linguistic knowledge, and so the present chapter reviews relevant neuroscientific studies from neuroscience on conceptual representation, categorization and language processing.

3.3 The Organisation of Language and Concepts in the Brain

The classical study of the organisation of language and conceptual knowledge in the brain has traditionally employed the lesion-deficit approach. The lesion-based approach is based on the observation patients with brain damage:

The functional role of a brain area is deduced from the observation of the cognitive impairment that arises after the brain area is damaged.

The lesion-deficit approach is based on the observation of the functional impairment (in a certain task) that follows damage to a specific brain area (Bookheimer, 2000). The contemporary lesion-deficit approach has been used in studies going back to the 19th century that have documented the cases of patients with impaired cognitive function after suffering brain damage: the famous case of Phineas Gage (1848, although the case was not studied until the 1860s) who presented personality changes and unruly behaviour after damage assumed to be in the left frontal lobe (Damasio et al, 1994). More relevant to the present research are the findings of Paul Broca (1863) who observed that patients with damage to the font part of the left hemisphere of the brain presented non fluent speech, poor sentence construction impaired speech, and abnormal intonation, and in in 1874, and also the description that Carl Wernicke provided on a type of aphasia -characterised by abundance of lexical errors and comprehension deficits- which occurred in patients with damage to the posterior portion of the of the left hemisphere. Another study examined the case of a patient with intact visual perception and recognition and intact speech capabilities who could not name an object after seeing it, but could name it after touching it with his hands. This condition was named "optic aphasia" (Freund,1881), since it presented the symptoms of a disorder that would not result from neither aphasia (language impairment) nor visual agnosia (brain impairment in the identification visual stimuli) .

However, the first important attempt to explain optic aphasia in terms of a deficit in the conceptual system was the work of Lhermitte and Beauvois (Lhermitte & Beauvois, 1973; Caramazza & Mahon, 2006), who suggested that optic aphasia resulted from a disturbance situated *"either among neuronal populations which process visual information into messages to speech mechanisms or upon their connexions en route to the temporal region*" (p. 709)**.** This explanation established the basis of the first theories on conceptual representation. Beauvois (1982) proposed an organisation of the conceptual system based on both a visual semantic system and a verbal semantic system. Under this organisation, optic aphasia would result from a disconnection between the visual semantic system and the verbal semantic system, and therefore, conceptual knowledge could be assumed to be organised in modality-specific systems (note that here, modality refers to the type of perceptual input: visual, tactile, auditory and so on).

Modality Specificity and Attribute Specificity

The dissociation between visual and linguistic knowledge raised the issue of whether visual knowledge about objects is represented differently from non-visual knowledge of objects (Kan et al., 2003). This question is, in turn, related to the more general debate on whether conceptual knowledge is based on perceptual representations (i.e. in form of visual features) or whether it is based on amodal, propositional abstract representations (i.e. in form of linguistic propositions) (Barsalou, 2008; Pylyshyn, 1981). More specifically, the question is whether to retrieve the knowledge of an object, such as a flower, the human brain needs to access the conceptual (abstract) knowledge of a flower, or whether the brain accesses the perceptual representations that are active when interacting with a a flower, such as visual imagery (color, shape) and others (smell, touch).

Visual imagery has been linked to the debate about language and the nature of conceptual representations, Paivio (1971) systematically measured mental imagery and a function of memory performance, and proposed a the dual-code theory, which assumed the existence of independent symbolic (linguistic) and sensorimotor (visual) systems. However, a major shortcoming of the dual code theory is that it did not account for perceptual input other than visual, and some authors have suggested that the idea that words and images are the only elements used to represent conceptual information is debatable (Pylyshyn, 1981). Another theory of conceptual representation states that conceptual knowledge is composed of different attributes that are distributed across different domains: for instance, Allport (1985) argues that word meaning would be the sum of attribute domains that are distributed, such as visual elements, action-oriented elements or tactile elements. Some authors have provided support for the notion that conceptual knowledge is organised according to perceptual representations: Kan et al., (2003) examined activation in the visual association cortex during a property verification task, and found activation in the left fusiform gyrus (visual association cortex) in the condition in which access to conceptual visual knowledge was required compared to the condition where a correct answer could have been produced without access to the conceptual system. Along these lines, Martin, Ungerleider et al. (2000) showed that regions of the ventral temporal cortex, fusiform gyrus are tuned to specific features of object form (based on evidence that this region of the cortex is organised by object category). Adding to the debate on the role of different perceptual systems in conceptual representations, a line of research has examined the relationship between the processes supporting mental imagery and those supporting perception.

Category Specificity Impairments and the Sensory/Functional Theory

The models of conceptual organisation discussed earlier do not explain the cases of patients with brain damage who exhibit deficits when processing certain categories and not others. In 1984 Warrington and Shallice documented the error patterns of four patients who were recovering from herpes simplex encephalitis (a viral infection of the human nervous system which causes neurological damage, predominantly to the temporal lobes) and presented visual identification and comprehension deficits. The patients were tested in identification tasks of visual versus verbal stimuli, inanimate objects versus living things and foods versus inanimate objects. In the task, the patients were required to identify the objects by naming or describing sets of pictures. Additionally, the researchers provided a comprehension task of abstract and concrete words where patients had to give the definition of a given word. For all cases there were consistent and significant deficits in their ability to discriminate living things and food, while discrimination of inanimate objects was preserved. In light of these findings, the authors proposed the sensory/functional theory. The sensory/functional theory builds upon the modality-specific hypothesis (Beauvois, 1982): In addition to suggesting that the conceptual system is organised by the modality or by the attributes of the object, the sensory/functional theory assumes that the identification of an inanimate objects depends on its functional significance, while identification of foods and living things involves semantic systems based on other sensory features (Warrington & Shallice, 1984). The sensory/functional theory assumes that brain damage to areas that host a modality or type of information results in category impairment: damage to the visual/perceptual areas would result in an impairment in recognizing living things (i.e. animals), while damage to the functional/associative brain areas would result in impairment in recognizing inanimate things (i.e. tools).

Several authors have defined “functionality” as an attribute that is defined by physical and motor properties (i.e. manipulability) rather than perceptual/sensory attributes (Caramazza & Mahon, 2006). Additionally, a number of studies have addressed the interrelation between function and motor processing: Petersen et al (1988) was the first study to report activation in the left prefrontal cortex associated with retrieval of action words. Later studies such as Grafton, Arbib et al(1996), reported increased activity in the left premotor cortex in conditions that required the retrieval of actions associated with tools, and also Grossman et al (2002) reported increased prefrontal ad lateral temporal activity during semantic processing of verbs of motion.

Further research provided findings which are consistent with the sensory/functional theory. Some studies report impairment in identification of living animate things (animals) in comparison to living inanimate things, such as fruits and vegetables (Hart & Gordon, 1992; EW: Caramazza & Shelton, 1998). Additionally, another study with brain damage patients found disproportionate impairment in living inanimate things compared to living animate things (Crutch & Warrington, 2003).

Research supporting a conceptual organisation based on categories is not limited to neuropsychological cases. Research with healthy participants has extensively used category production and picture naming tasks in conjunction with neuroimaging techniques (Thompson-Schill, 2003): for instance, a PET study by Martin & Wiggs (1996) reported activity in the left medial occipital cortex associated with the naming of pictures of animals, while activity in the left premotor and middle temporal cortex was associated with naming pictures of tools. Damasio et al. (1996) found activity in the temporal pole of the left hemisphere, associated with naming familiar people, activity in the inferior temporal lobe associated with naming animals, and activity in the anterior lateral occipital region and inferior temporal lobe associated with naming tools.

According to Caramazza et al. (2006), in the human conceptual system, living beings are characterised by a high number of visual features (colour, shape, patterns of movement in the case of animals), than non-living things, because of the evolutionary importance of living beings to human survival (food to obtain, predators to avoid). Accordingly, damage to modality systems results in increased impairment in the processing of living things, compared to non-living things, given that visual information is more salient and important in living beings. On the other hand, things whose processing relies on non-visual information do not present such a deficit.

However, several studies have reported the cases of patients who present deficits across modalities in their knowledge of living things, which suggests that this explanation needs to take into account that modalities are interrelated. Moreover, these findings are consistent with the notion that semantic memory is a “collection” of systems that are functionally and anatomically different (Caramazza et al., 2006), as opposed to the idea that memory is an amodal, unitary system.

Most current theoretical views on semantic memory (in the sense of conceptual knowledge) assume that the content of semantic memory is related to perception and action, and that this knowledge resides in brain areas that are involved in perceiving and acting (Barsalou, 2008). One perspective –the distributed domain specific hypothesis model- assumes that conceptual knowledge arises from the interaction of different brain areas that process sensory, motor, affective information. Under this model, neural circuits exist for certain categories that are shaped by evolution, such as animals, (Caramazza &

Mahon, 2011). In a different interpretation of this view, Damasio et al. (1989) proposed the existence of brain areas that act as “convergence zones” that hold information from different modalities. For instance, one of such convergence zones would connect visual information about object shape and information about actions that are available for the interaction with the object. In this case, the brain area would be involved in the processing of tools, rather than animals.

However, findings of studies with patients affected by a particular type of dementia have caused researchers to revise their theoretical positions on the nature of conceptual representation.

In 1989, Snowden et al. described dementia patients who presented anomia (failure to recall words or names), difficulties with recognizing objects, generalizing categories and general knowledge of facts, but who had preserved cognitive functions such as short term and episodic memory, visual-spatial function, executive functions and general intelligence. Snowden called this type of disease “semantic dementia”. Additionally, unlike stroke patients, the performance of patients with semantic dementia did not improve with the aid of cues during the task, and conceptual knowledge appeared to fade away progressively, with the advance of the disease, rather than being disrupted suddenly as in other conditions, such as stroke (Lambon-Ralph & Patterson, 2008). Patients recovering from semantic dementia present damage to both anterior temporal lobes, although some authors report that atrophy is usually larger in the left than in the right hemisphere (Mion et al, 2010).

The degree of impairment in “semantic” tasks in SD patients is associated to the severity of the disease, but also the familiarity and typicality of the objects: the impairment is more evident for atypical (less familiar) things (Patterson et al., 2007), while neural damage associated with other diseases produces conceptual impairment which is, to some extent, category or modality-specific.

A distinctive aspect of semantic dementia is that the loss of conceptual knowledge is distributed across all modalities and categories (Mion et al, 2010). The amodal nature of the conceptual disruption, together with the consistent pattern of neural damage (in the anterior temporal lobe) in SD patients has led to the rise of the 'spoke-plus-hub' model (Patterson, 2007; Pobric et al., 2010), which explains conceptual organization as a relation between modality-specific knowledge and amodal knowledge.

The Distributed View or Spoke-Plus-Hub Model

Coltheart et al. (1988) argued that perceptual information is distributed across the sensory motor systems and a nonperceptual system that is organised in categories. The nonperceptual system would hypothetically mediate between perceptual knowledge and linguistic knowledge. A re-elaboration of the theory of Coltheart et al. is the distributed plus hub model (or distributed plus spokes model).

The distributed plus hub model (or hub plus spokes model) proposes the existence modality specific areas that host perceptual representations (shape, color, smell, and so forth) and an amodal hub that is assumed to integrate information from all modalities, and is recruited in tasks that require interaction between modality specific regions or between conceptual and perceptual information.

Under this model, damage to the hub would result in the loss of conceptual knowledge that is independent from input modalities, but contrary to the distributed domain-specific model, this pattern of impairment would not arise from focal damage to specific modalities. In this sense, the distributed plus hub model is consistent with empirical data from semantic dementia studies, and given that semantic dementia patients present a consistent pattern of damage to the anterior temporal lobe (ATL), so this region has been hypothesised to be where the location of the amodal "semantic" (conceptual) hub. Furthermore, given that, in SD patients, the damage to the ATL is bilateral, some authors have suggested that the left and the right ATL might have different roles within the conceptual system. Specifically, the left hemisphere has traditionally been associated with language comprehension and production, while the left ATL is hypothesised to play a role in linguistic representations. For instance, Lambon et al. (2001) reported that the degree of anomia was higher in patients with more damage to the left than to the right ATL.

The study of patients with semantic dementia is not without limitations. It has been suggested that the fact that SD is a neurodegenerative disease implies that more subtle damage might be present to areas other than the ATL, -damage to areas that could be equally responsible for the impairment- (Martin, 2007). More specifically, some authors have reported SD patients with brain damage to the left fusiform gyrus, middle and superior temporal gyrus, hippocampus, amygdala and thalamus (Mummery et al., 2000). Other authors point out that the exact boundaries of the damage to ATL in SD are not universally agreed upon

(Pobric et al., 2010; Wong & Gallate, 2012), and that the function of the ATL has been described inconsistently, with some authors proposing a role in the representation of conceptual knowledge, language processing (Binder el al., 2010) or socio-emotional cognition and knowledge about unique entities (Wong & Gallate, 2012).

The study of the ATL with fMRI in healthy participants avoids the problem of delimiting the extent of brain damage in SD. However, there are technical limitations: It has been widely known that studies using fMRI tend to report activation in the ATL less often than studies using PET (positron emission tomography), a phenomenon that has been attributed to a low signal-to-noise ratio due to the existence of air filled sinuses near the ATL (Patterson et al., 2008).

Some studies have used TMS (transcranial magnetic stimulation) a magnetic stimulation of the cortex in to simulate a temporary lesion and disrupt the function of a certain brain areas. The function of the area in question is then deducted by observing the impairment that arises from its disruption.

Lambon Ralph, Pobric & Jefferies (2009) used TMS applied to the ATL in a synonym judgment task. In the language condition, a probe word (i.e., “thief”) was presented on top of other three words: the target (i.e., “scoundrel”) and two unrelated distractors (i.e., “polka”, “gasket”). Participants were required to choose the synonym of the probe word. In the non-language condition, a probe number (i.e., “3”) was presented instead of a word, and three number choices were displayed below the probe number. Participants were required to choose the number that was closest in value to the probe. Stimulation of left ATL and left

ATL was associated with slower reaction times in the synonym condition but not in the number task. Even though the authors did not address word meaning, these results suggest that the ATL is involved in lexico-semantic processing. In a later study, Pobric et al. (2009) used TMS to examine whether amodal representations are stored in the ATL bilaterally, whether the left ATL is specialised in language representations or whether only the left ATL holds amodal representations, with the right ATL playing a lesser role.
TMS was applied to participants who performed a semantic association task using words and pictures. In the linguistic condition, a sample picture was shown alongside two other picture choices. Participants where asked to choose the picture that was most closely related to the sample. In the linguistic condition, the stimuli were words and participants were again asked to choose the word that was most closely related to the sample. Participants were slower in both tasks when TMS was applied, irrespective of whether TMS was applied to the left or the right ATL, thus supporting the notion that the bilateral ATL is associated with amodal representations.

Most research in SD and the ATL has used tasks where language is involved (naming, category production) yet few studies have addressed word meaning directly. In the present research, we will address how word meaning is organised in the different category types, and whether access to word meaning in L1 while performing tasks in L2 differs, depending on the type of category being processed.

Chapter 4

Stimuli and Rationale

4.1 Introduction

This section introduces the main body of research that occupies the present thesis. The four experimental chapters of this thesis revolve around three main goals: the first goal is the study of the behavioural and neural correlates of classical, homonyms and radial categories, as they are defined in the cognitive linguistics models (Lakoff, 1987)

The second goal of this research is the study of the relationship between language and thought, through examination of linguistically mediated concepts (more concretely, lexicalized concepts).

The third goal of the present research is to study whether bilingual speakers differ from monolingual speakers in the way their category systems and category boundaries are built and processed.

The organization of the experimental chapters in the present thesis are as follows: the present chapter gives a general description of the stimuli and participants used throughout the experimental chapters. Chapter 5 will examine how classical, homonymic and radial category boundaries are differentially affected by lexicalisation (lexicalised and non-lexicalised categories) and the presence of linguistic cues during a category membership judgment task, and how they are affected in bilingual and monolingual speakers. Chapter 6 will examine semantic priming effects (facilitation or inhibition) in a lexical decision task, in classical, homonymic and radial taxonomic and radial thematic categories.

Chapter 7 will describe an ERP study where participants performed a delayed semantic judgment task. The ERP study aimed at complementing the findings of the priming study, by providing insight into the time-course of processing of lexicalized categories

Finally, chapter 8 will describe an fMRI study that was conducted to build on the findings of the semantic priming (chapter 6) and ERP (chapter 7) studies, and to investigate the neural correlates and potentially different patterns of activation in lexicalized categories (classical, homonymic and radial) compared to non-lexicalised categories.

4.2 Stimuli Used in the Present Studies.

The linguistic stimuli used in the present research were composed of written word pairs presented in English (in the priming, fMRI and ERP studies) or in Spanish (in the category membership judgment study). Appendix 3 shows the stimuli used in the category membership judgment study, appendix 4 shows the stimuli used in the priming and fMRI studies, and appendix 6 shows the stimuli corresponding to the ERP study.

There were four types of stimuli: Spanish-wide ("s-wide") categories, related controls, unrelated controls and non- words.

“S_wide” Categories

s_wide categories were the primary type of stimuli; these consisted of categories that were wide in Spanish, narrow in English. These were categories that are lexicalized with a single word in Spanish but corresponded to two separate lexical categories in English – e.g., *dedo – finger/toe*. In English there is an obligatory distinction made between the body part attached to the end of the hands (*fingers*) and the body part attached to the end of the feet (*toes*). In Spanish *dedo* has a “wider” scope, and designates both fingers and toes. All linguistic stimuli of type s_wide were of this form—wherein Spanish had a single word category that corresponded to two separate word categories in English.

S_wide are the type of stimuli of primary focus here for two reasons. First, they allowed us to compare how category processing happens in s_wide (lexicalised) categories with how category processing happens in other types of categories that are not lexicalised (see control stimuli below), to determine whether lexicalization in L1 has an effect in processing of the same categories in the L2. It must be noted that, while the language of the tasks was always English, the bilingual participants in all four studies had Spanish as their L1.

The second reason why s_wide are the primary type of stimuli in the present thesis is because attending to the relationship between the members in each category, categories were divided into classical, homonymic, radial taxonomic and radial thematic types, so that comparing different types of categories was possible (different types of s_wide categories are shown in table 4.1, along with samples. Full lists of items used in each experiment will be presented with each study).

Classical categories were those categories that were defined in keeping with the objectivist view on categorization: for each category, there are sufficient and necessary sets of features, (i.e.: DEDO: +part of body, +appendix at the end of limb. +articulated), which establish a clear boundary between category members and non-members.

Homonymic categories were those for which there are two words, whose meanings are not related; in Spanish, those two meanings happen to be designated by the same form. An example of a homonymic category is *vela* (' sail', 'candle'). (Note that homonyms are not categories in the same sense as classical and radial types. However, homonyms are used in the present research because they can be seen as an "extreme" category, where distant meanings are designated by the same form.)

The third type of categories examined in this study corresponded to radial categories for which the conventional links were based on metaphoric or taxonomic links. Radial categories are defined as consisting of a central, primary use that has been extended to include other meanings. In the case of this set of radial categories (henceforth, "radial taxonomic"), the extensions are based on visual or functional similarities. The category *pata* '*paw'-'table leg'* has a central meaning of "leg of an animal" (*paw*). Due to the similarity between the function of an animal leg (sustaining the body of some animals) and a table leg (supporting the flat top where one can place things), *pata* (*paw)* has been conventionally extended so that in it also designates a table leg.

Another type of radial categories used were radial categories that have thematic links between members. In radial thematic categories, the central meaning of the word has been extended in such a way that the extended meanings of the word share an event or setting with the central meaning. For instance, the Spanish word *pesca* denotes both *fishing* and *catch.* These meanings are clearly related since one makes reference to the activity of catching fish (*fishing*) and the other meaning refers to the outcome of that activity (*the catch*)

	Classical	Homonyms	Radial taxonomic	Radial thematic
Spanish	*Dedo*	*Vela*	*Pico*	*Pintura*
English	*Finger, Toe*	*Sail, Candle*	*Beak, Pickaxe*	*Paint, Painting*

Table 4.1: Sample of the types of s_wide stimuli used throughout the present thesis

Related Controls.

Related control categories were conceptually similar to s_wide categories but were not lexicalized with a single word in Spanish. In order to examine the effects of lexicalization (to compare s_wide, as described earlier), a set of pairs of words that were deemed to denote entities having conceptual links similar to those of the entities denoted by the words in the s_wide stimuli were used. In the case of the related controls, however, Spanish (like English) has two separate lexical categories for the two items in the pair. Related control categories were constructed with two criteria in mind. The first was that related control words should denote pairs of items whose conceptual relationship would be as similar as possible to the conceptual relationship between words in the lexicalised categories. That is, the relationship between related control$_{\text{Word1}}$ and related control$_{\text{Word2}}$ should be as similar as possible to the relationship between s_wide$_{\text{Word1}}$ and s_wide$_{\text{Word2}}$. For instance, neither Spanish nor English have a single lexicalised category including both the elbows (*codo*) and knees (*rodilla*), so the related control category *elbow-knee* was selected to act as a comparison (control) for *dedo* (English *finger-toe*). To be more explicit, the relationship between an elbow and a knee is analogous to the relationship between a finger and a toe: a finger and a toe can be described as body parts attached to the ends of the limbs: upper limbs in the case of a finger and lower limbs in the case of a toe; similarly, the relationship between an elbow and a knee can be conceptualised as both being body parts (joints) and both belonging to limbs (upper limbs for elbow and lower limbs for knee).

The second criterion was that each of the members of the related control pair should be as similar as possible conceptually to each of the corresponding members in the s_wide category. In other words, the meaning of related control$_{\text{Word1}}$ should be as similar as possible to the meaning of s_wide$_{\text{Word1}}$, and the meaning of related control$_{\text{Word2}}$ should be as similar as possible to the meaning of s_wide$_{\text{Word2}}$. In this sense, a finger is "matched" to an elbow because both are upper body parts and a toe is "matched" to a knee because both are lower body parts. In a similar fashion, *clock-watch* (a category which is lexicalised in Spanish as *reloj*) was compared with *gauge-metronome* (*aguja* and *metrónomo* in Spanish, respectively, and therefore non-lexicalised): *clock* was matched to *gauge* (both are measuring instruments that are fixed in place) and *watch* was matched to *metronome* (both portable measuring instruments), and so forth. Summarizing, related control categories were used as a "control" condition for the lexicalised categories, in order to make it possible to study the effect of lexicalisation (see table 4.2 for an example of related controls across categories; see the individual studies for complete lists).

	Classical	Homonyms	Radial taxonomic	Radial thematic
s_wide	*Finger, toe*	*Sail, candle*	*Mud, clay*	*Neck, collar*
Related controls	*Elbow, knee*	*Propeller, light bulb*	*Slush, snow*	*Wrist, sleeve*

Table 4.2: Examples of related controls matched to s_wide stimuli across categories

For the selection of s_wide and related control items for use in the study, it was necessary to draw up a list of potential items and to carry out a preliminary study to choose the best items fitting these criteria. A preliminary list of target word pairs was drawn up, and in order to determine whether the unrelated word pairs showed a similar conceptual linkage as the s_wide pairs, a preliminary study sought speakers' judgments on the word relationships. The relatedness study is described later in this chapter.

Unrelated Controls.

Unrelated controls were word pairs that were "narrow" (i.e., had separate labels) in both Spanish and English, but in this case, there were no conceptual links between the entities denoted by the two words in the word pair. The purpose of having unrelated controls was to be able to compare category processing in s_wide (lexicalised) categories and related controls (non lexicalised but with conceptual links between words in each word pair) with processing in unrelated controls (non-lexicalised and with no conceptual link between the words in each word pair). An example of unrelated controls is *soup – screw* (Spanish= *sopa – tornillo*). In order to verify that the members of each word pair were conceptually unrelated, the preliminary study to be described below also included these items.

Non-words.

Non-words were used in the priming and in the fMRI studies (chapter six, chapter eight), since the task in the fMRI study involved judging whether character strings presented on screen were real English words or not. For this purpose, non-words were constructed using letter strings that do not correspond to any real word in English, but that had a form that was English-like (i.e., conformed to English phonotactics). Non-words were obtained from the ARC non-word database (Rastle, Harrington and Coltheart, 2002). One hundred and forty-one English-like non-words were generated using a combination of lengths (maximum word length=11 characters, minimum word length=4 characters), with a minimum of 2 phonemes, and only valid orthographic combinations and pronounceable words were selected. Words that sounded like real words at all when pronounced were avoided.

A high ratio of non-words, relative to words has been assumed to engage strategies such as retrospective semantic matching in making decisions about the relatedness of word pairs (Neely, Keefe & Ross, 1989). Additionally, according to Neely (1991) an increased ratio of non-words led to increased priming effects in high and low dominance words. In the behavioural and fMRI priming studies, the word to non-word ratio was 1.51 (428 words, 283 non-words). The relatedness proportion was 2.45 (304 related words, 124 unrelated words). In the ERP study, stimuli were all words. However, the relatedness proportion was 4.03 (242 related words, 60 unrelated words).

Non-linguistic Stimuli

Additionally, in the category membership judgment study (chapter five), images depicting category members were used. These will be described in detail in chapter five.

Summarizing, the types of categories described above enable us to address two experimental questions: first, the specific differences in category processing between lexicalized (s_wide) and non-lexicalised categories (related controls), and second, whether there are differences in processing lexicalized classical, homonymic, radial taxonomic and radial thematic categories.

4.3 Stimuli Norming

The research presented in this thesis concerns mainly two issues: The first is the comparison of different category types (classical, homonymic and radial) and second is the comparison of s_wide (lexicalized) with related control (non-lexicalised) categories. As a result, it is very important to ensure that any observed effects of category type and lexicalization are due to differences in the nature of classical, homonymic and radial categories or differences between s_wide and related control categories. However, given that the predominant type of stimuli used in this thesis are words, or word pairs, there is the possibility that participants' responses or processing might be influenced not only by word length and frequency and also by the strength of the semantic relation between words in each word pair.

Associative and Categorical priming

Associative relations are those that reflect word use, and word co-occurrence (e.g. bread - butter, spider-web) while semantic relations are based on a conceptual link (e.g. horse-donkey, apple-pear). Several studies have shown that priming occurs in the prime-target and targer-prime orders when the relationship between words is semantic/categorical, but priming only occurs in the prime-target order when this relationship is associative (Thompson-Schill et. al, 1998). In the present research, the behavioural and fMRI priming studies used categorically (semantically, even in the thematic condition) related (via the L2) stimuli, unrelated controls and non-words. However, in the ERP priming study (chapter 7) used associatively related word pairs, in the condition of 'related controls'. However, directionality was not an issue, given that primes and targets were presented in both directions: prime – target and target – prime.

Concreteness and number of lexical neighbours.

Chapter 5. Category membership judgment study:

Stimuli in he category membership judgment study used images depicting a superordinate category (e.g. tree) and subordinate members (e.g. a picture of an oak tree, a picture of a palm tree). In addition, one of the participant groups were presented with the word denoting the category ("Tree"). A list of the images and words used can be found in appendix 3.

The assessment of associative strength in chapter five was addressed with a naming task, a valid measure widely used in the psycholinguistic literature (Fazio et al., 2000). The 24 images corresponding to the labels used in chapter five were presented to a sample of twenty Catalan-Spanish bilinguals (eight females, twelve males, mean age =28) recruited in Ibiza, Spain. The specific instructions given to participants (in Catalan) were: "You are going to see an image that depicts a category. Please name the category that corresponds to the image. For instance, if you see a picture of a SPARROW, you would use the generic category name BIRD". In each item, participants were given a score of 1 if they correctly named the category. Nineteen of the twenty participants obtained the maximum score (24), while one participant scored 23. In light of this result, associative strength between images and their corresponding labels was deemed sufficient.

Chapters 6 (priming study) and 8 (fMRI study)

Given that chapters 6 and 8 used the exact same stimuli, these are addressed together. Concreteness ratings for primes and targets were obtained from the MRC psycholinguistic database (Coltheart, 1981), and number of lexical neighbours for primes only were obtained from the MCWord orthographic word form database (Medler & Binder, 2005). A repeated measures ANOVA was used to compare the number of lexical neighbours across category types. No differences between category types were found $F(1,19)=3.425$, $p > 0.05$ for number of lexical neighbours of the prime items. The same type of analysis was performed regarding Concreteness (repeated measures). Again, there were no differences between number of lexical neighbours between category types, $F(3, 21) = 1716.11$, $p > 0.05$.

Chapter 7. ERP study:

Stimuli for Chapter 7 varied slightly from the stimuli used in Chapters 6 and 8, so in this case, concreteness ratings for the Chapter 7 stimuli were obtained from the MRC psycholinguistc database, and number of lexical neighbours were obtained from the MCWord database. A repeated measures ANOVA was performed, in order to compare the number of lexical neighbours for each prime and target words across classical, homonymic, radial, related controls and unrelated controls. Analyses revealed no differences in concreteness ratings between groups, $F(4, 24) = 1020$, $p > 0.05$. As in the previous case, the same analysis was performed on the number of lexical neighbours of the prime words. No differences in number of lexical neighbours were found, $F(1, 19) = 1960$, $p > 0.05$.

Word Length and Frequency.

The studies in chapters 6,7 and 8 used words as primary stimuli. It was important to ensure that words across categories were as similar as possible in terms of word length and frequency, in order to avoid as much as possible the possibility that performance on a given category might differ from the others due to differences in one or more of these two parameters. As much as possible, choice of words were controlled for concreteness as well, in that all words were nouns, and the range of concreteness within categories was similar across categories. However, there were limitations on how much the stimuli could be controlled, since keeping the semantic relation between the two languages in the stimuli (word pairs that would be wide in one language and narrow in the other, and their matching controls) was the most essential element to manipulate in order to answer the research questions.

Word Length

Word length was seen as a factor that could potentially affect the timing of responses. The average word length for all words that were used as stimuli was: 5.10 letters (SD= 1.355) in items of the classical category, 5.585 letters (SD = 2.783) in homonyms and 5.60 letters (SD= 1.702) in radial category items. For timing, in the fMRI study (chapter 8), the length of the prime word was assumed to be relevant, as the study involved a masked priming task, while in the indirect priming study (chapter 6), the length of the target word was considered be relevant for the timing of the responses (because RTs were based only on responses to the target word)

To examine primed word length, a paired samples T-test revealed no differences between prime word length in classical items and homonyms (t_{20}=-1.722, p=.101), no differences between prime word length in classical items and radial items (t_{19}= .698, p=.494), and no differences between the prime word length in homonyms and radial (t_{19}= 1.281, p=.342).

In the case of target word length, there were no differences in word length between classical items and homonyms (t_{20}=-.456, *p*=.647), classical and radial (t_{19}=-.983, *p*=.338) or homonyms and radial (t_{19}=1.361, *p*=.189)

Word Frequency

For all words used in the studies, word frequencies were obtained from the BNC database and word frequency lists (Kilgarriff, 1995). In particular, word frequency was calculated taking into account occurrences of the word as a noun (not as an adjective or verb), and in the relevant singular or plural form. (i.e., if the study used *mouse*, occurrences of *mice* were not counted).
Since words displayed a wide range of frequencies, the average word frequency in each category as only measure was deemed to be insufficient in order to control for differences in word frequencies across categories. To ensure that word frequency was similar across categories, words within each category were classified into either low or high frequency, average word frequency within each subgroup was adjusted by eliminating words that deviated 1.5 SD from the mean. However we ensured that the number of words within each subgroup across categories remained similar. After adjusting word frequency across groups, categories were compared using a paired samples t-test. Prime word frequency was compared across categories. No differences in word frequency were found between prime classical and prime homonyms (t_{19}=.221, *p*=.828), between prime classical and prime radial (t_{19}=-.040, *p*=.969) or between prime homonym and prime radial (t_{19}=-1.653, *p*=.115). Similarly, comparisons across target words showed that there were no differences between target classical and

target homonyms (t_{19}=.704, p=.490), between target classical and target radial (t_{19}=-.248, p=.807) or between target homonym and target radial (t_{19}=-1.276, p=.217) (see table 4.3 for number of words and means in each subgroup)

	Classical		**Homonyms**		**Radial**	
	Prime	Target	Prime	Target	Prime	Target
LOW FREQUENCY	542.91	436.7	408	222	535.1	451.2
HIGH FREQUENCY	5873.9	5955.5	5494.4	4864.9	6595.5	5675.9

Table 4.3: Mean word frequency scores across categories. .Numbers represent frequency in 1M corpus

4.4 Semantic Relatedness

In order to ensure that the relation between words in lexicalised categories (s_wide$_{Word1}$ and s_wide$_{Word2}$) and the relation between words in non-lexicalised categories (related_control$_{Word1}$ and related_control$_{Word2}$) were as similar as possible, a preliminary study was conducted, in which a *semantic relatedness* questionnaire was composed and administered to monolingual English speakers. Ensuring that the relationship between words in lexicalized and non-lexicalised category types were comparable in terms of how related their word pairs were was especially important in order to avoid RT biases due to facilitation effects. An RT bias could happen if overall, the relationship between s_wide$_{Word1}$ and s_wide$_{Word2}$ was stronger than the relationship between related_control$_{Word1}$ and related_control$_{Word2}$, or vice-versa. The relatedness questionnaire was constructed in order to choose the optimal pairs of words that would minimize the possibility that RT differences found between target and control items might be attributable to reasons other than the fact that the target items were lexicalised and the controls were not lexicalized (one of such reasons could be, for instance, word relatedness).

The *semantic relatedness* questionnaire was completed by a separate sample of native monolingual English speakers. This questionnaire aimed at identifying whether the relation between words in lexicalised categories (s_wide_{Word1} and s_wide_{Word2}) and the relation between words in non-lexicalised categories ($related\_control_{Word1}$ and $related\_control_{Word2}$) were similar.

Stimuli

Ninety-five items questions were presented side by side in the following format: *A) Finger - Toe : B) Elbow – Knee* together with a Likert five-point relatedness scale (1 = *No similarities at all*, 2 = *Maybe some connection but not really similar*, 3= *I can't tell*, 4= *Rather similar*, 5= *Very similar*). In 76 of the items, a potential target S-wide pair occurred alongside a Related Control pair. In 19 of the 95 questions, items were distractors, which consisted of either a) unrelated word pairs in one item and related word pairs in the other or b) unrelated word pairs in both items. Figure 4.1 shows an example of all different types of items used in the questionnaire, the complete questionnaire can be found in appendix 1.

a) Lion-cat			b) Wolf-Dog	
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*
				X

a) Egg-Shell			b) Brain-skull	
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*
			X	
a) Stapler-paper			b) Shoehorn-car	
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*
X				

F*igure 4.1. Sample of the Semantic relatedness questionnaire with possible judgments*

Participants

The semantic relatedness questionnaire was administered to 16 English monolinguals (Mean age=44.125, SD = 19.805, 7 females, 9 males) who were able to speak or understand English only and who completed the questionnaire in 20 to 25 minutes. Participation was voluntary.

Procedure

Participants completing the semantic relatedness questionnaire were given the following instructions: "*Are the meanings of the 2 words in (B) related in a way that is similar to the way in which the meanings of the 2 words in (A) are related? Put an 'X' in the box that corresponds to your judgment*". Before completing the relatedness questionnaire, participants were given three example questions that were already given a rating: *Lion-Cat : Wolf-Dog,* (rated as "very similar"), *Egg-Shell : Brain-Skull* (rated as "rather similar") *and Stapler-Paper : Shoehorn-Car* (rated as "no similarities at all"). After reading the instructions and examples, participants were asked to complete the relatedness questionnaire.

Analysis and Results

In order to exclude items that varied from the mean relatedness score and could skew the average, the statistical mode of the relatedness ratings for each question was calculated based on the response to each question across participants. For target-control and control-target questions, the mode of the relatedness score ranged between 1.5 and five and for distractors, the score range was one to five. In order to avoid overlap between target and control items and distractors in terms of how related their items were, target-control and control-target questions that had obtained a relatedness score mode lower than three were discarded, and distractors that obtained a relatedness score mode higher than three were also discarded. The average of the relatedness mode was calculated for classical (average = 4.281), homonyms (average = 3.692) and radial (average = 4.3) categories. (The lower relatedness mode for homonyms can be explained by the fact that items within the homonymic category were not related, and thus were more difficult to rate).

Chapter 5

Category Membership Judgment Study

5.1 Introduction

The present study is a follow up to Viñas-Guasch (2008). The original study aimed at examining the processing of categories during a category membership judgment task using items belonging to classical categories, homonyms and radial taxonomic or radial thematic categories. An additional goal of the study was to compare whether categories would be processed differently when the target item was presented alongside a linguistic cue (a label naming the category) or not.

A very dynamic debate revolves around the question of whether the language people speak has an effect on the way they classify reality, and in particular, whether language affects their non-linguistic processing of category boundaries (Pavlenko, 2000). In Viñas-Guasch (2008), I conducted a study with English speakers and Catalan speakers, which examined whether there were differences in their processing of categories. In that study, there were two conditions: a language-linked condition and a non-linguistic condition. Categories belonged to classical, homonymic, radial taxonomic and radial thematic categories, as defined in chapter 4. Half of the categories corresponded to words that had a wider scope in English, and half corresponded to words that had a wider scope in Catalan. Thirty participants were Catalan speakers (who had very little or no knowledge of English; almost all Catalan speakers in Spain are also speakers of Spanish) and 30 were native English monolinguals. The Catalan-speaking group performed the task in Catalan, and the English-speaking group performed the task in English.

During a computerized task, participants were presented with a category exemplar image that depicted an object from a category, for 5000 ms. There were two conditions: the "label" (language-linked) condition, where the target image was accompanied by a written label naming the object, and the other condition was the "non-label" (non-linguistic) condition, where the image was presented without a label. Following the presentation of the target image, a blank screen was shown for 500 ms., and afterwards, a screen containing six more images was presented for 15 seconds. Each of the six images depicted items that were related to the target in different ways. Two of the six items (called T1 and T2) were members of the same category as the original category exemplar in the "wider" of the two languages. Two other items (Tax1 and Tax2) were related to T1 and T2 via taxonomic links, and the remaining two items (Them1 and Them2) were related to T1 and T2 via thematic links. Each of the six items was labeled with a letter ranging from 'A' to 'F'. Participants were asked to decide which of the items were "like" the category exemplar and to press the corresponding key on the keyboard. The specific instructions that participants received were: " You will now see a picture, followed by six other pictures, which are marked with the letters 'A', 'B', 'C', 'D', 'E' or 'F'. Please look carefully at all the pictures and press the keys corresponding to the objects that are 'like' the first one you see".

In the original Viñas-Guasch (2008) study, it was predicted that the percentage of category-congruent responses (choosing T1 and T2 in wide categories and choosing T1 in narrow categories) would be higher in the label (linguistic) condition than in the non-label (non-linguistic) condition for all participants. Additionally, it was hypothesized that category membership judgment of classical categories would be the least affected (positively or negatively) by the presence of a label, and also that in each language group, category membership would be more effortful in wider categories, in the sense that participants would tend to choose either T1 or T2 but not both more often than choosing both targets in narrow categories. (For simplicity, from now on, we will use the term "performance" to refer to the percentage of category-congruent responses).

As predicted, all participants in that study showed significantly higher performance (more category-congruent responses) when labels were presented alongside target items. Moreover, regarding the processing of different category types, performance was highest when participants made judgments about classical categories, next highest in relation to radial categories, next-to-lowest in relation to homonyms, and lowest when making judgments about radial categories with thematic links. Processing of "narrow" categories (narrower in Catalan/wider in English for the Catalan group and narrower in English/wider in Catalan for the English group) was associated with higher performance for each language group. In addition, the results showed an interaction effect of language by category type and width, whereby performance, for both languages, was better in the narrow condition in all category types except for classical categories. This effect suggests that in classical categories, judgement of category membership was less affected by category width.

In the original study it was argued that the comparatively higher performance in classical categories could be explained by the fact that these categories are the most homogeneous, and because meaning in classical categories largely overlaps with the conceptualization of the corresponding conceptual categories, classical categories are also the least dependent on language mechanisms of all four types of categories. Higher performance in "narrow" items was explained by considering that category membership is less divergent, meaning that there are fewer central members, and thus "narrower" items would be easier to respond to correctly than "wider" items.

One surprising result of the study was that overall performance was higher in the Catalan group than in the English group. It was hypothesized that the higher performance in the Catalan group might have to do with the fact that the Catalan speakers were all bilingual (albeit in Catalan and Spanish, two languages that share semantic structure of the categories tested).

Some research on bilinguals (Biaystok, 2001, Gathercole, 2010) suggests an advantage of bilinguals over monolinguals in a variety of linguistic tasks, so it is possible that the Catalan speakers performed better simply because of the fact that they were bilingual. An alternative hypothesis was that there is perhaps some aspects about the structure of Catalan, or the culture of Catalan speakers, that make Catalan speakers more attentive to the types of categories tested. The design of that study did not allow us to determine whether the difference in performance between the English and Catalan-speaking groups was related to the fact that one group was bilingual and the other not, or whether the difference in performance reflected something about the processing of the two languages, English vs. Catalan.

In order to address that issue, the present follow-up study was designed. Ideally, it would have been best to test monolingual Catalan speakers to examine whether they performed in the same way as the bilingual speakers. However, adult monolingual Catalan speakers are rare. So, in the follow-up study, we decided to test Spanish speakers, because the Spanish category organization for the categories used in this study is exactly the same as in Catalan, and because it is possible to find both monolingual and bilingual (in Spanish and Catalan) Spanish speakers. Consequently, this study used two groups who speak the same language, Spanish. One group consisted of monolinguals and the other group were bilinguals. The two groups had a similar SES background (students of psychology and education in public universities in Spain), both to each other and to the participants of the previous study. The present study used the same task and stimuli as the original 2008 study (except the labels were in Spanish), in order to examine the question of the best explanation for the superior performance of the Catalan speakers over the English speakers in the original study. This study compared the performance of a group of Catalan-Spanish bilinguals and a group of monolingual Spanish speakers. Since all participants were tested in Spanish, this comparison enables the study to determine whether there are possible differences in performance associated with being bilingual, which can then be compared with the previous study.

Predictions

The overall results in relation to category type, category width, and condition (language-linked or non-linguistic) are expected to be similar to those of the 2008 study. That is, performance is expected to be higher in classical and radial taxonomic categories, and lowest in homonyms and radial thematic categories; higher in the label than the non-label condition; and higher in narrow than in wider categories.

With regard to the two groups of participants, if the performance of the bilingual group is higher than the performance of the monolingual group, this will support a bilingual advantage in the processing of categories. If the two groups perform identically, then the results of the previous study can be attributed to a difference in performance associated with the particular languages being tested.

5.1 Method

Participants

Sixty-seven university students took part in this study. Thirty-two participants were Catalan-Spanish bilinguals (24 female, 8 male, mean age = 20.761 years, SD=0.82) recruited at the Universitat de les Illes Balears in Mallorca, Balearic Islands, Spain. Thirty-five participants were Spanish monolingual speakers (all female, mean age = 20.111 years, SD=0.451) recruited at the Universidad Autónoma de Madrid, Madrid, Spain. Participants were predominantly undergraduate Psychology and Education students from years 1 to 3. Participation was voluntary.

Information about language use and proficiency was obtained via a language background questionnaire (see appendix 2). Only participants who were bilingual in Catalan and Spanish or strictly monolinguals in Spanish were used in the study. Thirty-two participants in the Catalan-speaking group reported using Catalan at least 50% of their time, relative to Spanish. Two participants who reported a lower usage of Catalan were excluded from the analysis. Thirty-five participants in the Spanish monolingual group reported using Spanish only 100% of their time. A participant who reported using another language alongside Spanish was excluded from the analysis.

Apparatus

Participants were tested using a laptop computer running Microsoft Windows XP and PowerPoint 2003. The computer was connected to a projector, projecting slides onto a screen. Each slide contained six pictures. Participants were given a response sheet and were asked to mark their responses in boxes labelled A to F, corresponding to their choice of items shown in the slides.

Design

The task was identical to the one in Viñas-Guasch (2008), except that it was conducted in Spanish, and it consisted of 24 trials, 12 of which depicted categories that were "wider in English" (an English word designates two meanings) and 12 of which depicted categories that were "wider in Catalan and Spanish". Each of the 12-trial sets consisted of 3 classical categories, 3 homonymic categories, 3 radial taxonomic categories and 3 radial thematic categories. Half of the participants in each language group were randomly assigned to the "no label" condition and half were assigned to the "label" condition.

Since the stimuli used in the present study corresponded to the stimuli from the Viñas-Guasch (2008) study, half of the categories were "wider in Spanish/Catalan" (and narrower in English) and half of the categories were "wider in English" (and narrower in Spanish/Catalan). However, since there were no English-speaking participants in the present study, in the present study we will just use the terms "wider" for categories with a wider scope in Spanish and "narrow" for categories with a narrower scope of application in Spanish. In this study, "narrow" categories correspond to what in the Viñas-Guasch (2008) study were "wider in English" categories.

Stimuli

Linguistic stimuli. The linguistic stimuli in the present study consisted of a set of 24 categories, half of which were s_wide ("wider") and half of which were "narrow" in scope. As described in the fourth chapter, s_wide categories were those that, in Spanish, denoted more than one type of referent (e.g., *dedo* applies to both fingers and toes). "Narrow" categories only denoted one type of referent (e.g., *gafas* applies only to glasses in the sense of a device used to correct eyesight).

Both in the s_wide and narrower conditions, categories consisted of three classical, three homonymic, three radial taxonomic and three radial thematic categories.

The linguistic stimuli have been described in detail in chapter 4, in relation to all four experiments reported in this thesis. The list of items used in this experiment are shown in Table 5.1

	Wide	Narrow
Classical	**DEDO** (finger and toe) **RELOJ** (watch and clock) **CINTA** (ribbon and tape)	**ARBOL** (tree, excluding palm trees) **CAMPANA** (bell, church bell type only) **ABRIGO** (coat, clothing)
Homonyms	**BOTA** (boot and ask) **PLANTA** (plant and floor) **BANCO** (bank and bench)	**BAUL** (chest, container) **UÑA** (nail, body part) **BOLIGRAFO** (pen, writing instrument)
Radial taxonomic	**ESCALERA** (stair and ladder) **CAJA** (box and cash register) **ARCO** (arch and bow)	**LLAVE** (key, for opening doors) **PATA** (leg of a table, not human leg) **HOJA** (sheet of paper)
Radial thematic	**PINTURA** (paint and painting) **CUADRO** (painting and frame) **PLATO** (plate and dish)	**LETRAS** (letters, letters of the alphabet, not correspondence) **GAFAS** (glasses, eyesight correction device, not for drinking) **TE** (tea, beverage)

Table 5.1. List of items used in the present study

Non-Linguistic Stimuli.

Two types of slides were used in this study. At the start of each trial, a slide with a category exemplar image (an image which was used to represent a category) was presented.

The category exemplar that was shown at the beginning of a trial consisted of either a picture or a photograph at a resolution of 200*220 pixels, presented on a white background, with no other visual information other than the object itself. In the label condition, the category exemplar appeared with its name written below it, whereas in the non-label condition the category exemplar was presented on its own, without a label. The stimuli used can be found in appendix 3.

The slide that was presented after the category exemplar image depicted six images arranged in 3 columns and 2 rows. The images in the upper row were labelled with the letters “A” “B” “C”, starting from the left of the row, and those in the lower row were labelled “D” “E” “F”, starting from the left of the row. All images were shown at a 1027*768 pixel resolution and in 32-bit colour. In half of the trials, the images were drawings, whereas in the other half they were photographs (pictures and photographs were balanced across categories). Pictures and photographs were never combined in any trial, in order to avoid certain items being more easily recognised or more salient within a trial. Additionally, all images had a similar level of complexity with no text and no other visual information other than the object itself depicted.

The slides depicting the six images were composed of two target items (T1 and T2), two items taxonomically associated with T1 and T2 (Tax1 and Tax2, respectively) and two items thematically associated with T1 and T2 (Them1 and Them2, respectively). T1 was essentially a different version of the category exemplar that had been shown in the previous slide (i.e., a different image of an object of the same kind). The second target (T2) was another object equally representative of that category in wide but not in the narrow categories (T2 was a potential referent for the corresponding word in English in such cases). (See Figures 5.1 and 5.2.)

Figure 5.1. Sample layout of a narrow trial in the categorization task. *Gafas* = "eyeglasses". Since this is a narrow category, there is only one target (T1). The only category congruent response in this case is choice E.

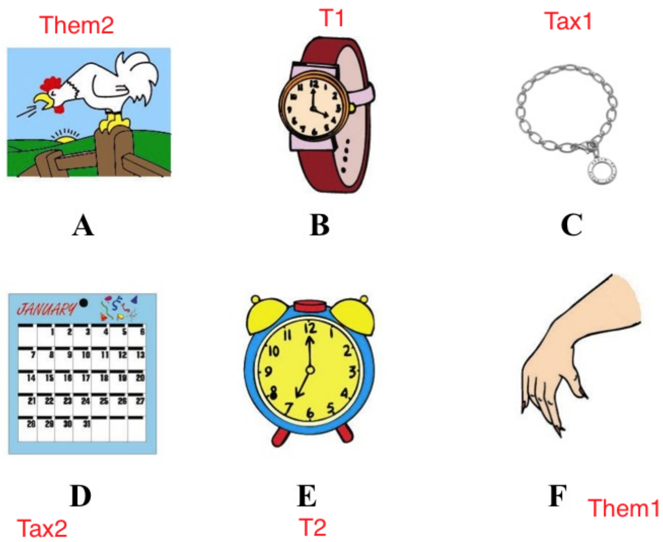


Figure 5.2. Sample layout of a wider trial in the categorization task. *Reloj* = "timepiece" (watch and clock). Since this is a wider category, there are two targets (T1 and T2). The category congruent responses in this case are B and E.

The image presentation sequence was balanced to ensure that every kind of item appeared an equal number of times in each screen position. As in the original study, half of the trials (12) consisted of “wider” categories, and half consisted of “narrow” categories.

Procedure

Participants were presented with a total of 28 trials, of which the first was an example slide (see figure 5.3) followed by three practice trials, used to ensure participants understood and became familiar with the testing procedure.

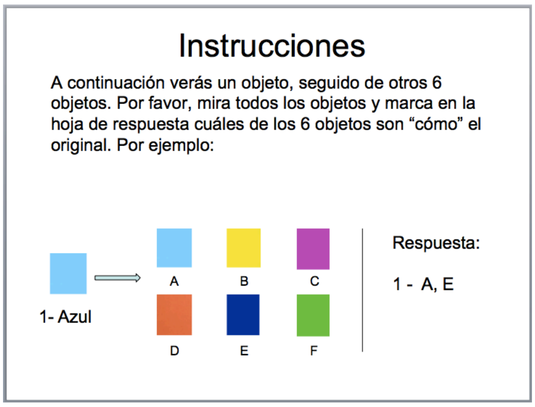


Figure 5.3. Instructions slide in the categorization task. Translation: “You will now see an object, followed by 6 other objects. Please look at all objects and mark in the response sheet which of the 6 objects are “like” the original. For example: 1-Blue; Answer: 1-A, E. In this case, it was clarified that “like” did not strictly mean identical.

The practice trials were the same for both language groups, but they differed in the label and non-label conditions, in that a label appeared under the category exemplar only in the label condition. The practice items had the same form as the experimental items, in that the first slide showed a category exemplar, and the second slide showed the 6 choice items. Additionally, at the end of the practice trials, a slide showed the correct choices (see figure 5.4). Participants were instructed not to write anything on the response forms during the practice trials.

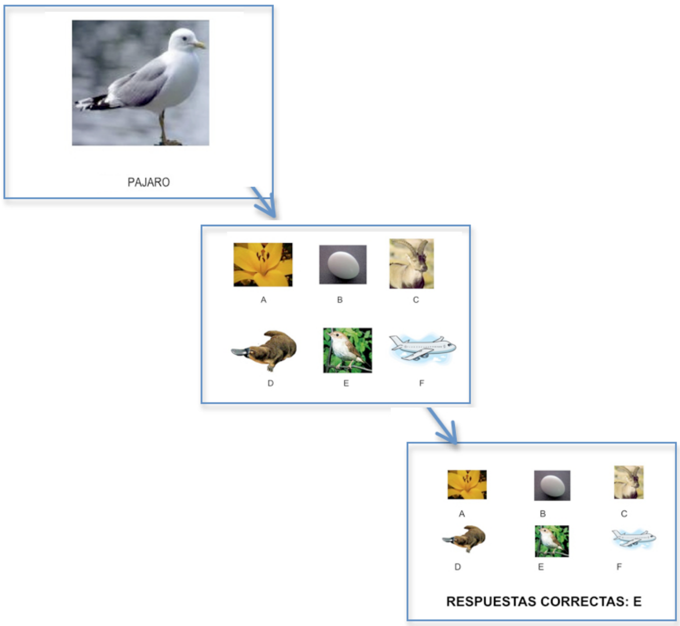


Figure 5.4. Sample layout of a practice trial in the categorization task (label condition). *Pájaro* means "bird" in Spanish. In this case, the only congruent response, or correct (*respuesta correcta)* is E. The image on the left is the category exemplar.

Each trial began with the display of a category exemplar image, depicting a category, for five seconds. Following the presentation of the category exemplar, a blank screen was shown for 500 ms., followed by a screen showing six items, presented for 15 seconds.

5.2. Results

Analysis by Percentage of Category Congruent Responses

Task performance was assessed according to the percentage of responses that were congruent with the category being judged. In “wider” trials, responses were coded as category congruent, and were given a score of one, when participants chose both T1 and T2, since T1 and T2 were denotations of the word in the Spanish language. An example of a category congruent response would be, in the wider target *dedo*, when participants chose the image depicting a finger and the image depicting a toe, since in the Spanish language, *dedo* applies to both fingers and toes. In “narrow” trials, responses were coded as category congruent (again, being given a score of one) if only T1 was chosen, because in Spanish, only T1 is a referent of the category. Thus, for example, in response to *letra* (‘letter’), speakers of Spanish would be expected to choose the image depicting an alphabetic letter, but not a “message” letter, since *letra* in Spanish only encompasses the meaning of “alphabetic letter” (a “message” letter is *carta*). For each participant, the number of category congruent responses was computed for classical, homonym, radial taxonomic and radial thematic categories, in both wider and narrower conditions, yielding eight scores per participant. The data were analyzed using SPSS. A GLM repeated measures ANOVA was performed with category type (classical, homonym, radial taxonomic and radial thematic) and width (wide and narrow) as within-subjects factors and language group (bilingual and monolingual) and label group (label or no label) as between-subjects factors.

The analysis revealed significant main effects of category type, $F(3,61)=34.89$, $p<0.001$, Language group, $F(1,63)=6.416$, $p<0.05$, Label group, $F(1,63)=22.1519$, $p<0.001$ and Width $F(1,63)=406.204$, $p<0.001$. The Analysis also revealed significant interactions of Category Type x Width, $F(3,61)= 406.264$, $p<0.001$, and Category Type x Width x Label Group, $F(3,61)=7.215$, $p<0.001$. No other significant effects were found.

Category Type

Post-hoc analyses (LSD) of the effect of category type revealed that overall, participants achieved a higher performance when processing classical categories (mean = 0.838) than homonymic (mean = 0.724) ($p<0.001$), radial taxonomic (mean = 0.788) ($p=0.002$), and radial thematic (mean = 0.722) ($p<0.001$) categories. Moreover, performance in radial taxonomic categories was also significantly higher than in homonymic ($p<0.001$) and radial thematic ($p<0.001$) categories. However, differences in performance between homonymic and radial thematic categories were not significant ($p=0.888$).

Language Group

The overall performance of the bilingual group was significantly higher (0.795) than the performance of the monolingual group (0.740), $p<0.05$. This is consistent with the findings from Viñas-Guasch (2008). Note that this higher performance was present in virtually every condition, (see discussion).

Label Group

The main effect of label condition revealed that participant performance was significantly higher in the label condition (0.819) than in the no label condition (0.717), $p<0.05$.

Width

The main effect of width revealed that participant performance was significantly higher in narrow categories (0.917) than in wide categories (0.619), $p<0.05$. The higher performance shown in narrower categories might be due to the fact that participants had to choose only one target (as opposed to two in the wider condition), so the chance of making errors was smaller.

Category Type x Width

The interaction of Category Type x Width revealed that participants performed differently across the four category types in relation to wide vs. narrow categories: A GLM ANOVA revealed that when making judgments about wider categories, participant performance was significantly higher in classical than in all other types of categories, $F(3,64)=62.808$, $p<0.001$. Additionally, pairwise comparisons revealed that performance in homonymic categories was significantly lower than classical ($p<0.001$), radial thematic ($p<0.001$) and radial taxonomic ($p<0.001$) categories. However, there was no significant difference in performance between radial thematic and radial taxonomic categories.

A repeated measures ANOVA GLM revealed that when participants processed narrow items, performance was significantly lower on radial thematic categories than on classical (*p*<0.001*),* homonymic (*p*<0.001*)* and radial taxonomic (*p*<0.001*)* categories $F(3,64)=5.665$, $p<0.001$. Performance on classical, homonymic and radial taxonomic categories did not differ significantly. Participants' performance across category types in wider and narrower categories is shown in Figure 5.5

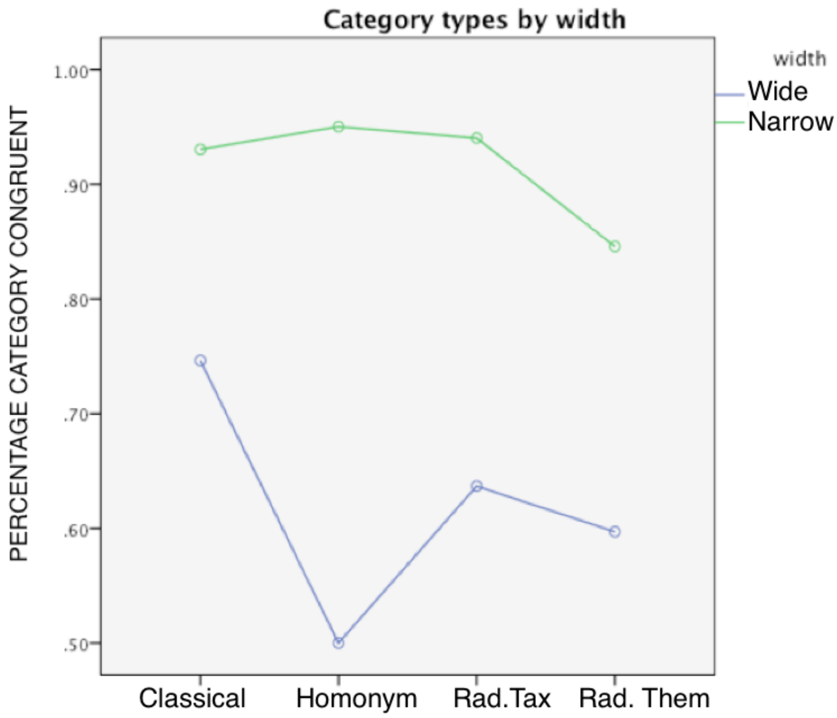


Figure 5.5. Differences in performance by category width across category types in all participants.

Category Type x Width x Label group

The overall interaction of Category Type x Width x Label group is shown in figure 5.6, further ANOVAs were performed for each width separately.

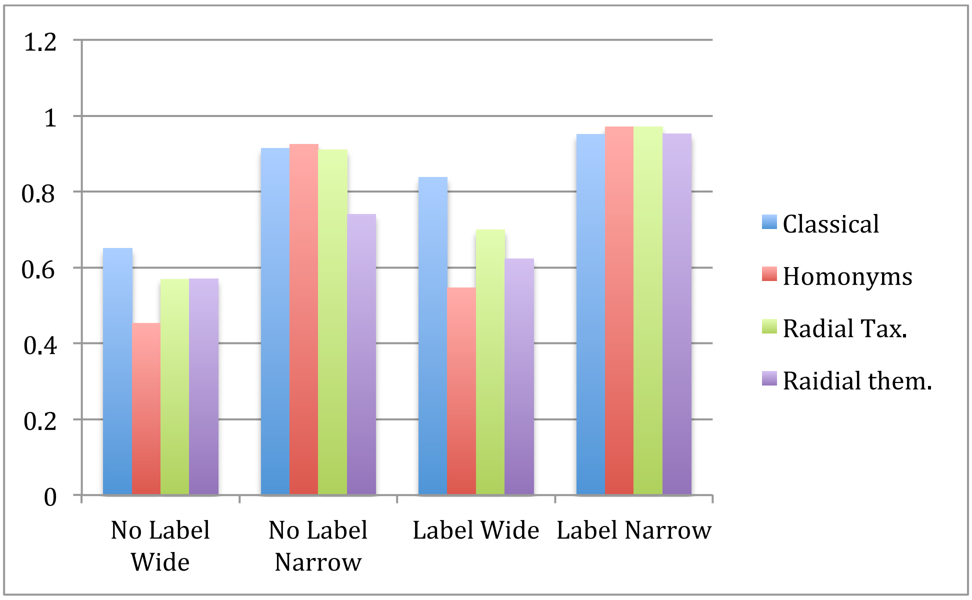


Figure 5.6. Overall performance (in percentage of correct responses) in wider and narrower items across category types in the label condition.

Wider Categories

Separate ANOVAs for each category type in the wide condition by label group showed that classical, homonyms and radial taxonomic items that were wider in scope were associated with significantly higher performance in the label condition than in the non-label condition: classical, $F(1,65)=37.584$, $p<0.001$, homonymic; $F(1,65)=9.717$, $p<0.001$; radial taxonomic, $F(1,65)=10.363$, $p<0.01$, but in the case of radial thematic categories, the difference in performance in the label and non label conditions was not significant, $F(1,65)=2.773$, $p=0.101$ (see figure 5.7).

Narrow Categories

Separate ANOVAs for each category type in the narrow condition by label group showed that in contrast to the wider items, only narrow items in radial thematic categories were associated with significantly lower performance in the non-label condition compared to the label condition, $F(1,65) = 9.717$, $p<0.005$ (see figure 5.8),

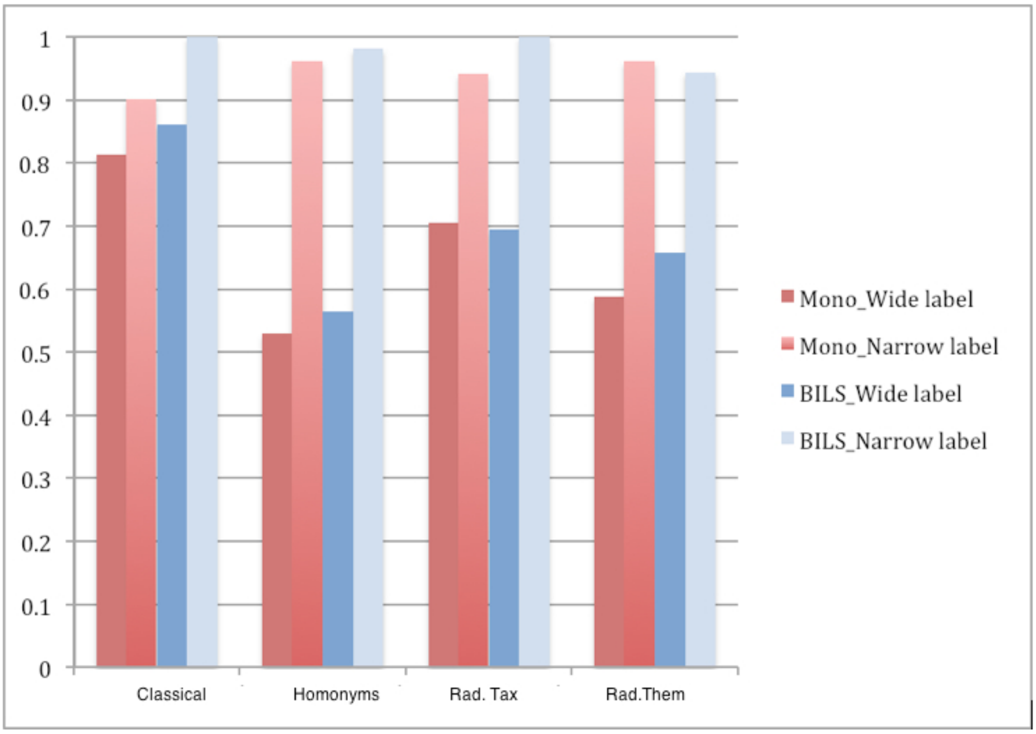


Figure 5.7. Performance in percentage of correct responses in wider and narrower items by language groups across category types in the label condition.

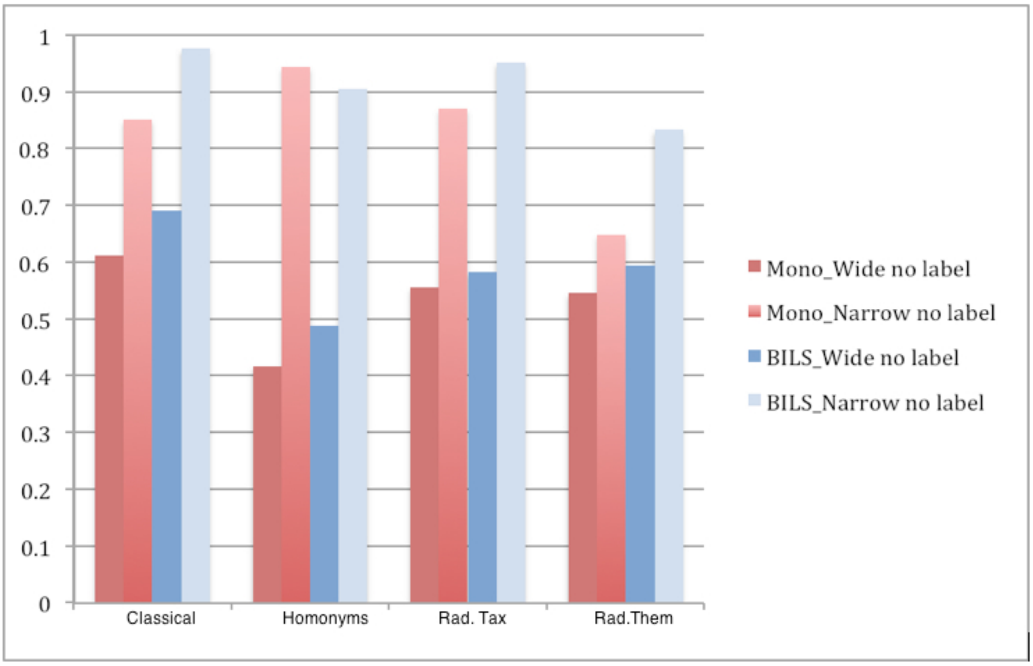


Figure 5.8. Performance in percentage of correct responses in wider and narrower items by language groups across category types in the non label condition

Analysis of Overextensions

In addition to the analysis of target choices, a further analysis examined the overextensions participants made beyond the targets (T1 and T2) by choosing taxonomically or thematically related distractors[1]. Participants' overextensions could be taken as an indicator of how flexible category boundaries were for them. Moreover, the patterns of overextensions could provide more information about the process of categorization; for instance it might be the case that the presence of a linguistic label entices the participants to adopt a more restrictive scope of categories thus resulting in fewer extensions. Furthermore, it could be that overextensions occur more often in certain category types than in others, or it could be that participants in one language group apply category boundaries more liberally than those in the other language group.

Responses were classed as overextensions when participants chose distractor items (tax1, tax2, them1 or them2), independently from the choice of target items. In these cases, overextensions were coded as "1". For instance, if in the trial *Finger*, participants chose the image depicting a tiger claw (tax1), the type of overextension was considered to be taxonomic (a finger and a claw are conceptually similar, except for that one applies to humans and the other one applies to animals). On the other hand, if participants chose the picture depicting

[1] Technically speaking, such extensions beyond T1 and T2 are "overextensions" when a label is involved. Without a label they are not technically overextensions in a linguistic sense. However, for simplicity's sake, for the purposes of this section I will refer to these choices beyond T1 and T2 as "overextensions".

a ring (them1), the overextension was classed as thematic, given that a ring and a finger are related thematically (a ring goes on a finger and so on).

A repeated measures ANOVA was performed, using Category type, Language group, Label group and Overextension type (taxonomic or thematic) as variables. The main analysis showed an effect of Category type $F(3,61) = 12.964$, $p<0.001$, Language group $F(1,63) = 17.085$, $p<0.001$ and Label group, $F(1,63) = 36.257$, $p<0.01$.

In regards to category type, pairwise comparisons showed that participants made more overextensions in radial thematic categories (1.398) than in classical (1.120), $p<0.05$, homonymic (0.796), $p<0.001$ and radial taxonomic categories (1.067), $p<0.05$. Additionally, participants made more overextensions in classical categories than in homonyms, $p<0.05$ and more overextensions in radial taxonomic categories than in homonymic categories, $p<0.01$. Regarding language group, bilinguals made more overextensions (1.422) than monolinguals (0.768), $p<0.05$.

In the case of label group, more overextensions were observed in the non-label (1.571) than in the label condition (0.619).

The main effects of Category type, Language group and Label group were modulated by interaction effects of Category Type x Label Group, $F(3,61) = 16.367$, $p<0.001$, Category Type x Overextension Type, $F(3,61) = 19.922$, $p<0.001$, Overextension Type x Language Group, $F(3,61)$ 8.434 , $p<0.05$, Overextension Type x Label Group, $F(3,61) = 5.312$, $p<0.05$, Language Group x Label Group, $F(1,63) = 9.564$, $p<0.01$, Category Type x Language Group, $F(3,61) =$

4.901, $p<0.01$, and Category Type x Overextension Type x Language Group, $F(3,61) = 5.270$, $p<0.01$.

Performance by Category Type X Overextension Type X Language Group is shown in Figure 5.9. To explore the interaction effects, separate ANOVAs were performed for each category type, with overextension type, label group and language group as variables.

Classical Categories

A separate analysis of classical categories revealed that there was an effect of overextension type $F(1,63) = 4.706$, $p<0.05$, with more taxonomic (1.161) than thematic (0.782) overextensions. There was also an effect of language group $F(1,63) = 6.524$, $p<0.05$, with bilinguals producing more overextensions (1.218) than monolingual speakers (0.725). Furthermore an effect of label group was found $F(1,63) = 10.712$, $p<0.01$, with participants in the non label group producing more overextensions (1.288) than participants in the label group (0.655). A comparison of the types of overextensions in each language and label group across categories is shown in figure 5.9.

Homonyms

An analysis of overextensions for the homonyic categories revealed effects of overextension type $F(1,63) = 9.022$, $p<0.01$, with overall more taxonomic (1.606) than thematic overextensions (1.054). There was also an effect of language group, $F(1,63) = 13.965$, $p<0.001$, with bilinguals producing more overextensions (01.681) than monolinguals (0.979). There was also an effect of label group, $F(1,63) = 48.875$, $p<0.001$, with more overextensions in the non-label group (1.986) than in the label group (0.673). Additionally, main effects were modified by an interaction effect of Language Group x Label Group, $F(1,63) = 19.344$, $p<0.001$. Follow-up analyses for monolingual and bilinguals separately revealed that the bilingual group was associated with a larger difference in number of overextensions between label (0.611) and non-label (2.750) conditions (difference = 2.139), compared to monolinguals' overextensions in label (1.222) and non-label (0.735) conditions (difference = 0.487), $p<0.01$. See Figure 5.9.

Radial Taxonomic Categories

The analysis of overextensions with radial taxonomic categories showed an effect of language group, $F(1,63) = 13.934$, $p<0.001$, again with bilinguals producing more overextensions (1.292) than monolinguals (0.596). There was also an effect of label group, $F(1,63) = 9.836$, $p<0.01$, with the non-label group showing more overextensions (1.236) than the label group (0.652). Furthermore, there was an interaction effect of Overextension Type x Label Group, $F(1,63) = 4.213$, $p<0.05$. Follow-up analyses, in which, overextension type and label group were used as variables showed that participants in the label condition (but not those in the non-label condition) made significantly more taxonomic overextensions (0.938) than thematic overextensions (0.366), $p<0.05$. This effect is shown in figure 5.9.

Radial Thematic Categories

In regards to overextensions in the radial thematic categories, there were effects of overextension type $F(1,63) = 40.618$, $p<0.001$, but, in contrast to all the other category types, there were more thematic (1.713) than taxonomic overextensions (0.529). Additionally, there was an effect of language group, $F(1,63) = 15.400$, $p<0.001$, with bilinguals producing more overextensions (1.498) than monolinguals (0.774). There was also an effect of label group, $F(1,63) = 48.084$, $p<0.001$. Specifically, there were more overextensions in the non-label group (1.776) than in the label group (0.496). In addition to the main effects, there were interaction effects of Overextension Type x Language group, $F(1,63) = 15.169$, $p<0.001$. Follow-up analyses for each language group revealed that in the bilingual group, the average number of thematic overextensions (2.476) was significantly higher than the average number of taxonomic overextensions (0.520), $p < 0.001$.

The analysis also showed an interaction effect of Overextension Type x Label group, $F(1,63) = 12.983$, $p<0.01$. Follow-up analyses in which overextension type, and label group were entered as variables revealed that participants in the non-label condition produced significantly more thematic (2.726) than taxonomic overextensions (0.825) $p < 0.001$, Finally, there was also an interaction effect of Language Group x Label Group, $F(1,63) = 5.641$, $p<0.05$. A follow-up analysis for each language group separately revealed that bilingual speakers showed a larger difference in number of overextensions between label (0.639) and non-label (2.357) conditions (difference = 1.718), compared to monolinguals' overextensions in label (1.194) and non-label (0.335) conditions (difference = 0.859), $p<0.05$, see figure 5.9.

Language Group By Label Group Interaction Effects

A post-hoc analysis of the interaction effect of Language Group x Label Group revealed that in the non-label condition, there were more overextensions made by the bilingual group (17.143) than the monolingual group (8), $F(1,31) = 19.873$, $p<0.001$, whereas there was no difference in number of overextensions by language group in the label condition ($p=0.396$).

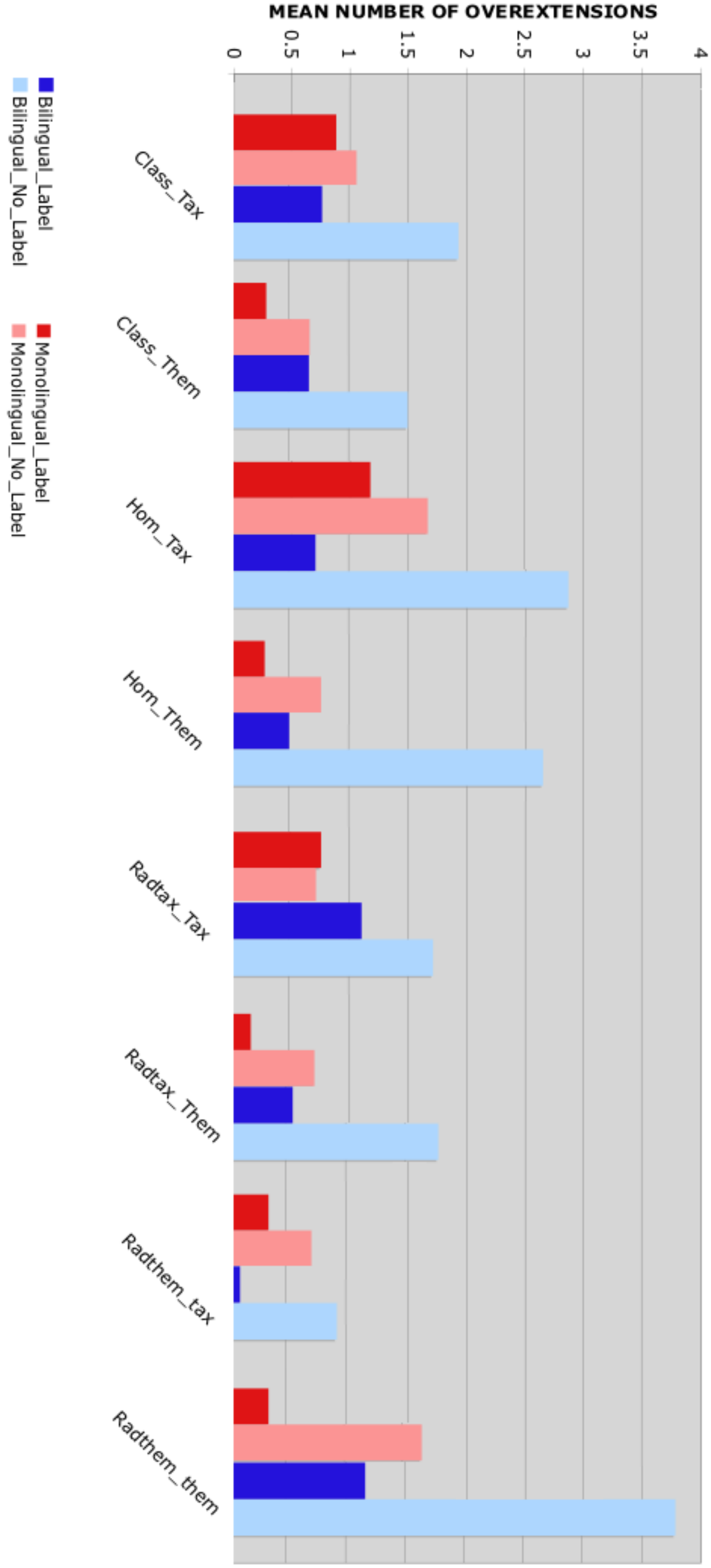


Figure 5.9. Overextensions by language group across category types.

5.3 Discussion

Category Congruent Responses

The results of the present study suggest that category type, width and presence or absence of a label all have an effect on judgments of category membership and the types of overextensions that participants make. Additionally, the results show differences between monolinguals and bilinguals in their judgment of category exemplars, which suggests that bilingualism, as a factor, might have an effect on performance, at least in categorisation tasks that involve visual stimuli.

Performance on the choice of targets—i.e., for which participants judged T1 (narrow categories) or T1 and T2 (wide categories) to be members of the categories depicted by the category exemplars – showed the following pattern: Participants showed highest overall performance in classical categories, followed by radial taxonomic categories, and lowest performance in homonymic and radial thematic categories. Furthermore, participant performance was higher in narrow categories than in wider categories, and also higher in the label than in the no-label condition. Finally, overall task performance was higher in the bilinguals than in the monolingual group.

Higher performance in classical categories, in the wide condition and in the label group are in line with the findings of the Viñas-Guasch (2008) study. In the 2008 study, it was hypothesized that classical categories were more reliant on conceptual knowledge and less on language mechanisms than the other category types. Given that membership judgments in this task (comparing images of objects to see if they are members of the same category) involves both visual and conceptual mechanisms), judgments on classical categories might be less effortful.

Regarding category width, the findings of the present study, and also of the 2008 study suggest that higher performance on the targets in the narrow condition might be due to narrow categories having only one target, and therefore being easier to respond to than wider items, because participants did not have to choose as many members and therefore may have been less likely to involuntarily omit a target. In terms of label group, performance was always higher when a label was presented alongside the category exemplar. It was hypothesized that the presence of a label might provide a linguistic cue that leads participants to narrow down their focus onto the target items that are relevant to the specific category, while ignoring the irrelevant distractors. Another possibility is that the presence of a label entices participants to select items that share the same lexical label. However, this interpretation is complicated by the fact that, in the wide condition there were differences in performance in the processing of classical, homonymic and radial taxonomic categories (where participants are expected to choose T1 and T2), but not for radial thematic categories. Additionally, in the s_wide condition, processing of classical, homonymic and radial categories improved with the presence of a label, but such improvement was not shown in radial thematic categories. In contrast, in the narrow condition (where participants are expected to choose only T1), performance in classical, homonymic and radial taxonomic categories was not altered by the presence or absence of a label, while performance in radial thematic categories was significantly degraded in the absence of a label, which suggests the possible inhibition effects of L1 semantic retrieval when processing radial thematic categories.

Perhaps the most striking result is the difference in performance between the monolingual Spanish group and the bilingual Spanish-Catalan group. All participants were tested in Spanish, and, as noted above, the categories tested have identical structure in the bilinguals' two languages. In Viñas-Guasch (2008), performance of the (bilingual) Catalan group was higher than that of the (monolingual) English group. That difference in performance had not been predicted, because the categories had been carefully chosen so that half the items for each language were narrow in that language and half were wider. The 2008 study was designed in such a way that the items wider in Catalan were narrow in English and those that were narrow in Catalan were wider in English, but given that the Catalan speakers were not speakers of English, the differences in performance between those groups could not be attributed to an effect of transfer from one language to the other in the bilinguals. As discussed at the outset, there were only two differences between the participant groups: one was the language tested, the other was that one group consisted of bilinguals, the other monolinguals. It was speculated that one possible explanation for the effect could be that the Catalan language or culture per se caused the Catalan group to be more attentive to the type of stimuli used in this study, while another, more feasible hypothesis, was that it was the fact of being bilingual that influenced performance, leading the Catalan speakers to be more "careful" in respecting category boundaries than the monolinguals.

In the present study, both language groups were tested in the same language, Spanish, but we still found differences across the participants' performance. The language being tested could not be responsible for differences in performance across groups. The much more plausible explanation for the differences across the groups is that the fact of being bilingual influences speakers' attention in a task such as the present one, which involves category membership judgments[2].

If this interpretation is correct, it provides an important result that has ramifications for the interpretation of any study that pits monolinguals against bilinguals, at least in relation to an examination of their semantic processing. When monolinguals are compared to bilinguals in such studies, it is usually to determine whether bilinguals show effects of transfer from one of their languages to their other language. Any differences in performance are interpreted as arising from such effects. The results of this study make interpretations of results in such studies more challenging. There was no possibility here of the bilinguals' performance being influenced by the structure of another language (in this case, English). Nevertheless, the bilingual speakers showed differential performance relative to monolinguals, due apparently to the simple fact that they were bilinguals. Additionally, the increased performance associated with the bilingual group is in line with findings in previous literature, which suggests increased executive control for bilinguals. In this case, it appears that bilinguals were more attentive to the task than monolinguals: overextending

[2] We cannot, of course, totally rule out the possibility that the higher performance of bilinguals might be due to factors in Catalan culture that lead Catalan speakers to be more attentive to categories in any language they speak.

more in the absence of a label ("focusing harder" to find similarities between the items) but not in the presence of a label ("respecting" the category boundary).

Overextensions

The analyses of the number of overextensions made by all participants showed that the overall lowest number of overextensions occurred in homonymic categories, while radial thematic categories exhibited the highest number of overextensions. As predicted, the presence of a label was associated with a lower number of overextensions, and overall, bilinguals produced more overextensions than monolinguals.

A potential explanation for the low number of extensions associated with homonyms is that when making decisions about category membership in homonyms, participants were enticed to choose T1 (the target that was perceptually most similar to the category exemplar), and to ignore T2 (even in the wide condition). Since T2 was ignored, any distractors related to T2 (tax2 and them2) were also ignored, which resulted in an overall lower number of overextensions in the homonymic category. We hypothesised that when processing homonymic categories, participants need to rely more on linguistic information, since the information on links between category "members" is conventionalized by the speaker's language, rather than there being a conceptual relation between referents. Given that judging category membership on pictures of things requires visual and conceptual processing, it was expected that more overextensions would occur in categories that rely less on language mechanisms and more on visual features.

Nevertheless, in regards to label group, the results are in line with the notion that the presence of a label aids participants in focusing on the category and the relevant category members and ignore any distractors.

Regarding language group, overall bilinguals produced more overextensions than the monolingual group. This might potentially indicate that bilinguals' category boundaries are more flexible than those of monolinguals, or again, that bilinguals are being more or less careful in “respecting” category boundaries depending on the presence or absence of a linguistic label. This hypothesis is in line with the notion that bilinguals' category systems need to be flexible in order to accommodate how different languages construct categories. Conversely, the fact that monolinguals do not show any differences in percentage of overextensions in the label and non-label conditions can be attributed to their category boundary systems being less flexible than those of monolinguals, and therefore less susceptible to the influence of a linguistic label.

The analysis of the type of overextensions participants made revealed that in all but radial thematic categories, there was a higher number of taxonomic overextensions than thematic overextensions. This again lends support to the hypothesis that participants tended to consider things to be category members when they shared a set of common conceptual or visual features (i.e. choosing the picture of a bush as being ‘like’ a tree instead of choosing the picture of a leaf). Interestingly, radial thematic categories differed in this sense, because the overextensions in this case were predominantly of thematic rather than taxonomic, which again indicates that radial thematic categories are substantially different from the other category types.

Another interesting result concerns the fact that linguistic labels have an effect on category boundaries. There was increased accuracy and reduced overextension in the label condition than in the non-label condition. The fact that different categories were affected by the presence or absence of a label (especially radial thematic categories) further supports the distinction of different category types. In this case, a tendency to seek new associations or overextend conceptual (non-linguistically mediated) could reflect either the structure of a conceptual system with less delimited category boundaries, or conceptual system similar to that of monolinguals, but decreased control in “respecting” category boundaries than monolinguals.

If the reason behind the higher percentage of overextensions in bilinguals was decreased control, we would have expected a poorer performance than the monolinguals also in linguistic mediated categories. Given that this was not the case, an explanation based on a decrease of executive control can be ruled out. Summarizing, we can suggest that the higher percentage of correct responses and overextensions observed in bilinguals might be due to two factors: on the one hand, bilinguals were flexible in switching from a non-linguistic task (in the non-label condition) to a linguistic task (the label condition), a fact that is consistent with previous literature that reports a “bilingual advantage” in tasks that require executive control (Gathercole et al., 2010; Bialystok, 1999),

On the other hand, the observed tendency towards overextension of conceptual categories is consistent with the notion that languages direct the process of category formation in cognitive development. Some scholars (Francis, 2005; Murphy, 2001) have previously argued that the bilingual lexical system might differ qualitatively from the monolingual one, rather than being the sum of the lexical systems in language A and language B. The need to accommodate two (or more) lexical systems, where each lexical system "carves" the conceptual space in a specific way can lead to a convergence of these systems, manifested, for instance, in naming tasks (Ameel 2005, 2009). Given the results of the present study, we propose that the phenomenon of convergence is not exclusive to the – lexico-semantic system, but also occurs in the conceptual system. The experimental chapters that follow explore this possibility.

Implications For The Relationship Between Language And Thought

Taken together, these findings have implications for how linguistically and non-linguistically mediated knowledge relate to the lexico-semantic system. In both participant groups, classical categories were the least affected by width (whether these were lexicalised or not). Classical categories were treated as "conceptual", non-linguistically mediated categories. However, performance in this case was improved with the addition of a label, although this improvement was smaller than in the other category types.

In homonyms, performance was the lowest of all category types. Given the visual/conceptual nature of the task, a plausible explanation for this finding is that the conceptual relationship between items in homonyms is either weaker than in classical categories, or there is no conceptual relationship, but only a lexical relationship (that is, of sharing the same word form). Consequently, the relationship between homonymic items might be only apparent in tasks that involve access to the lexical system.

Radial categories are the most informative about the relationship between the lexical-semantic and conceptual systems. Performance both in the Radial thematic and Radial taxonomic categories is consistent with the notion that the different, extended meanings of radial categories are conceptually related, but this relationship is not as salient as in Classical categories nor is it as obscure as in homonyms. However, performance when judging membership in radial thematic categories seems to improve with the presence of a label more than when judging any of the other category types, including homonyms, which were the “category” type hypothesized to be most aided by the presence of a label, given that there was no conceptual relation between items. The fact that performance in judging radial thematic categories was even higher than homonyms suggests that in the absence of a label, bilingual participants might be inhibiting access to the conceptual system.

Additionally, only in Radial categories was the overextension type modulated by the presence or absence of a label, where radial taxonomic categories in the label condition were associated with more taxonomic (conceptual) extensions, whereas radial thematic categories in the no-label condition were associated with more thematic extensions

Chapter 6

Priming Study

6.1 Introduction

The previous chapter introduced a study in which bilingual and monolingual participants performed a category membership task on a set of classical, homonyms, radial taxonomic and radial thematic categories. Additionally, there were language and non-language conditions. Percentage of correct responses varied across categories, conditions and also between language groups. Overall performance was highest in classical categories, lowest in homonyms and radial thematic categories and intermediate in radial categories, and also higher in the language condition (where words were presented) than in the non-language condition. Additionally, performance of the bilingual group was higher than that of the monolingual group. These findings suggest that the way classical, homonymic and radial categories might be processed or represented in substantially different ways, and it was hypothesised that classical categories are the least susceptible to linguistic interference, homonyms and radial thematic categories being the most susceptible and radial taxonomic categories taking an intermediate position between classical categories and homonyms (although radial thematic categories exhibited a particular pattern, different from the rest of categories.

As stated earlier, a potential explanation for the differences in performance across categories is that processing of classical categories relies on visual and functional features, and are the least linguistically dependent of all four types of categories. Under this assumption, word meanings in classical categories would map onto a common superordinate category in the conceptual space. In the case of homonyms, which are idiosyncratic and conventionalised in each language, more specifically, two words might be homonyms in a language but not in another (for instance, *mango* in Spanish means both *mango* and *handle* in English). Homonyms can be seen as a purely linguistic artefact, since the only relationship between the meanings is that they share the same word form, so hypothetically, the word form would map onto two different entities in the conceptual space.

Additional support for the notion that categories are less susceptible to linguistic interference comes from the results of the previous chapter: participant performance did increase when homonyms were presented with a linguistic cue in the task (a label) , but this benefit was not present in classical categories.

However, further comparison of category types are necessary to support the notion that categories are represented at both semantic and conceptual levels.

The present study aims to contribute to the understanding of how semantic and conceptual knowledge are interrelated. To achieve this goal, monolingual and bilingual participants were tested in an indirect priming task in which sequences of prime and target word pairs were presented (in principle, without participants being aware that there were related word pairs) alongside unrelated words and non-words that were pronounceable and looked like English words.

“The prime-target word pairs in this study were previously rated for relatedness by another English monolingual group, in order to avoid a bias in relatedness in the hypothetical case that word relatedness was higher in certain categories than in others (see chapter 4 for more details on the semantic relatedness study). Since the goal of the study was to explore the effect of the L1 on L2 in a bilingual group, the choice of a lexical decision task was important, in order to minimize bilinguals explicitly accessing their L1 (Spanish) during the task. While there is evidence for automatic access to the L1 when processing L2 words in semantic decision tasks (Thierry & Wu, 2008), as well as in lexical decision tasks (Grainger & Jacobs, 1996), implicit access to L1 was seen as a potential problem if an explicit relatedness judgment or a category membership task had been used.”

6.2 Method

Stimuli

The present study used s_wide categories, related controls, unrelated controls and non-words. Seventeen items were classical categories (matched to 17 related controls), 13 were homonyms (again, matched to 13 related controls), 9 were radial taxonomic (with 9 matching related controls) and 16 were radial thematic (with 16 matching related controls). Additionally 42 items were unrelated word pairs and 140 items were English-like non-word pairs (see chapter 4 for a more detailed description of the stimuli). The stimuli used in the present study can be found in appendix 4.

Participants

Thirty-three participants took part in this study, 18 native English monolinguals (14 female, 4 male) and 15 native Spanish speakers who had English as their second language (10 female, 5 male). The English monolingual group consisted of native English speakers who were born in England but who were studying a degree at Bangor University, in Wales, UK. Mean age for the English monolingual group was 20.13 years (range 18-29 years, SD= 2.3). The Spanish-speaking group consisted of participants born in Latin America (n=8) or in Spain (n=7) who were working or studying in North Wales. Mean age for the Spanish group was 33.4 years (range 23-54 years, SD=7.77). While there was a considerable difference in age between the bilingual and the monolingual groups, which could potentially affect overall reaction times, examining reaction time differences between the two language groups was not the objective of the present study. Slower reaction times for bilinguals, compared to monolinguals in linguistic tasks are well documented in previous studies (Michael & Gollan, 2005), and therefore reaction time differences between language groups were already expected. Additionally, given that English was the second (non native) language of the bilingual group, it would be expected for the bilinguals to be overall slower since they were using their second language throughout the task.

The Spanish-speaking participants completed a language background questionnaire (see appendix 5) where they reported having at least 9 years of experience in speaking English (mean=19.8 years, SD= 8.59). Spanish-speaking participants also reported their competence in reading and understanding English as high or very high. Additionally, to ensure that the knowledge of the English vocabulary was reasonably comparable between Spanish speaking and English speaking participants, the British Picture Vocabulary Scale (standardised for adults) test (BPVS; Dunn, Dunn, Whetton & Burley, 1997) was administered to all participants. In the vocabulary test, the experimenter read aloud a word, and the participant was shown four pictures from which they had to choose the picture that best matched the word that they previously heard.

Regarding performance in the BPVS test, the bilingual group obtained a standardised score of 140.86 (SD=3.66) and the monolingual group obtained a score of 140.89 (SD=3.49). A means comparison between groups showed no significant differences in BPVS scores ($p<0.01$). The results suggest that the two language groups were reasonably comparable in their knowledge of basic English vocabulary.

Procedure

All testing was performed with a laptop computer with a 15-inch screen running a script in E-prime 2.0 (E-prime Psychology Software Tools Inc., Pittsburgh, USA). Stimuli were presented in a white font on a black background, with a font size of 48. Participants were asked to place their right index finger over the ‘P’ key on the computer’s Qwerty keyboard and their left index finger over the ‘Q’ key. Participants were then instructed to watch the stimuli appear on screen and, as quickly as possible, to press ‘P’ if the word was a real English word and ‘Q’ if it was a non-word. The instructions were followed by five practice trials during which the experimenter checked whether participants understood the procedure and clarified any questions regarding the task. Participants who did not understand the procedure performed the five practice trials until the procedure was clear to them. The experimenter encouraged the participants to respond as quickly and accurately as possible. The experiment started after the practice trials.

Each trial started with a fixation cross, which was presented for 500 ms., followed by a prime word (the first word in a pair). Participants then made a response as fast as possible pressing the keys on the keyboard. However, words and non-words remained on screen until a response was made, so the trials were effectively self-paced. Once a response was made, the word was replaced by a fixation cross shown for 500 ms., followed by the target word, which also remained on-screen until a response was made and the trial finished. Presentation of all 292 trials was randomised for each participant. After the computerised task was finished, participants were asked to complete the British Picture Vocabulary Scale.

Predictions

Based on the behavioural data of other categorization studies (Gathercole et al., 2010; Viñas-Guasch's unpublished 2008 study), and for the reasons mentioned earlier, we can assume that the Spanish-speaking group will show slower overall performance (reaction times). Additionally, Spanish bilingual participants processed stimuli in their second language, which, intuitively, should prove to be slower than access to their first language. For this reason, RTs for bilinguals and monolinguals cannot be compared directly. However, RT comparisons within language groups are possible.

The bilingual Spanish group is expected to show differences in reaction times between s_wide and control items. Hypothetically, taking the analogy of a neural network, given that s_wide categories are encoded in a single word in the Spanish language, it could be that access to one of the meanings partially activates the other meaning, yielding faster reaction times in s_wide categories than in controls.

On the other hand, regarding the monolingual English group, small or no differences in reaction times are expected between s_wide and control items, because the English language does not encode the s_wide categories in single words. However, regardless of group (s_wide or control), the classical categories used in this study consist of word pairs that are conceptually related (i.e. finger and toe), so there is the possibility that even in the monolingual English group, reaction times in classical categories might be reduced, compared to homonyms and radial categories.

Furthermore, it is expected that there will not be any significant differences in reaction times in unrelated and control categories in the Spanish group, except for perhaps classical categories, for the reason highlighted above. In the monolingual English group, no differences in reaction times between categories are expected, but again, related controls matched to classical categories might be an exception.

6.3 Results

Scoring for Reaction Times

Reaction times for target words were measured as the time elapsed between the presentation of the word and the response of the participant. Each trial finished only when the participant made a response. Consequently, there were no trials left without a response.

Presentation of stimuli took place sequentially (prime$_1$, fixation cross, target$_1$, prime$_2$, fixation cross, target$_2$, and so forth), thus allowing for the possibility that processing of prime words would be influenced by the processing of preceding target words. Since the study only controlled for relationship between a prime and a target within each word pair, measures of relatedness between each possible combination of target words and primes were not available. Consequently, only reaction times for target items were included in the analysis. However, participants were required to make a response on both primes and targets, in order to ensure that participants processed primes and targets with the same level of involvement.

Main analysis

A repeated measures ANOVA analysis was performed on reaction times for target words. Factors used in the analysis were Category type (classical, homonyms, radial or radial thematic), Condition (s_wide and control) and Language group (bilingual and monolingual). The repeated measures ANOVA revealed a significant effect of Language group, F (1,31)=17.19, p<0.01, with the bilingual group showing overall slower reaction times (mean =840.75 ms.) than the monolingual group (mean =521.67 ms.), and an effect of Category Type, $F(3,29)=7.22$, $p<0.01$, with classical categories in both language groups associated with slower reaction times than the other category types, and homonyms associated with significantly faster reaction times than radial categories (see figure 6.1).

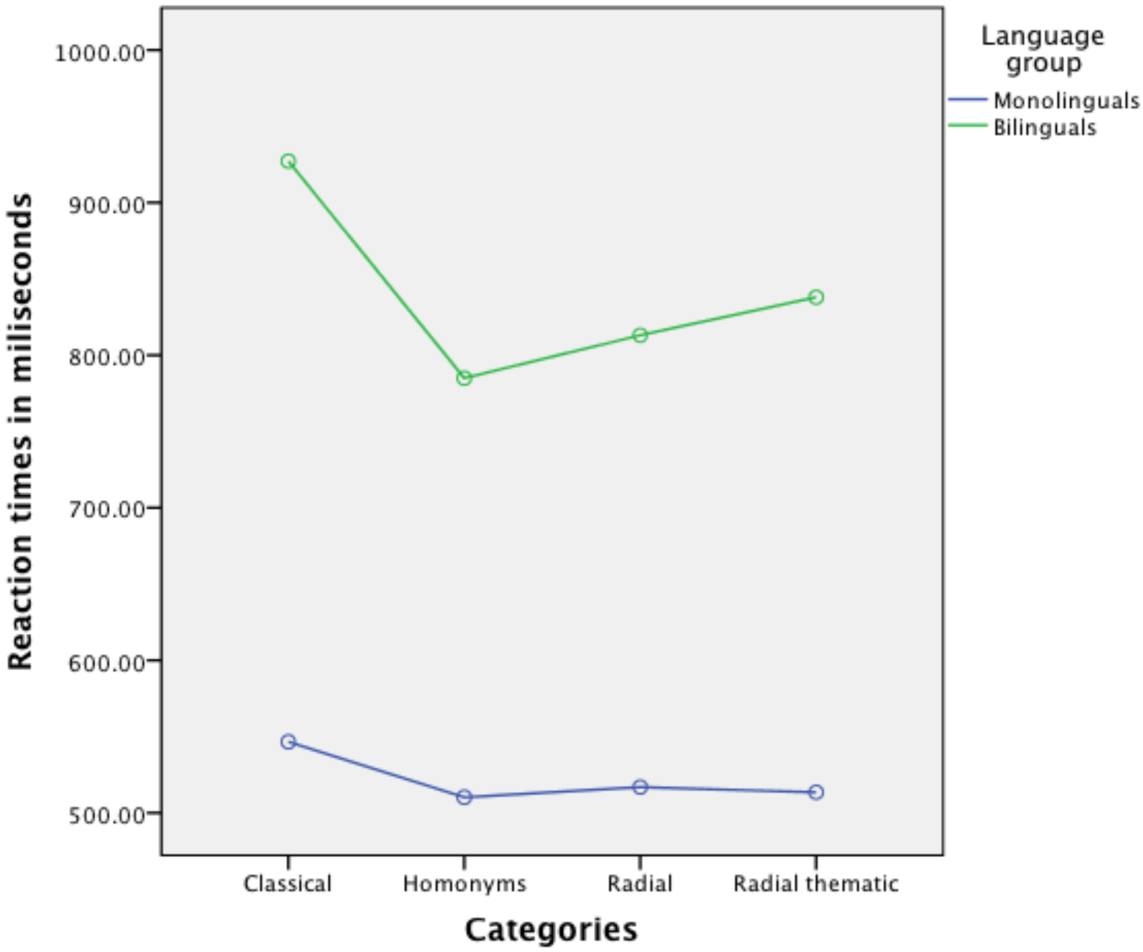


Figure 6.1. Overall mean reaction times by category and language group.

Additionally, there were significant interaction effects of Category Type x Condition, $F\ (1,31)=27.74$, $p<0.01$, in which classical items in the control condition were processed slower than in the s_wide condition. Furthermore, there were interaction effects of Category Type x Language Group, $F(1,31)=4.95$, $p<0.05$.

Finally, a three-way interaction effect of Category Type x Condition x Language Group was revealed, $F(1,31) = 8.81$, $p<0.05$. Separate analyses for each language group are discussed below.

Analyses by Language Group

Bilingual Group

Analysis of the bilingual group revealed a significant effect of Category type, $F(3,42)=4.32$, $p<0.01$. Pairwise comparisons showed that overall reaction times for classical categories were slower than for homonyms, radial and radial thematic categories. Additionally homonyms were overall processed significantly faster than radial thematic categories. Furthermore, the comparisons showed a significant interaction effect of Category type x Condition, $F(1,14)=16.17$, $p<0.01$, in which reaction times for classical categories in the control condition were significantly slower than in the s_wide condition ($p<0.05$), and reaction times for radial thematic categories were significantly faster in the control than in the s_wide condition($p<0.05$). Figure 6.2 shows reaction times for categories in s_wide and control conditions for the bilingual group.

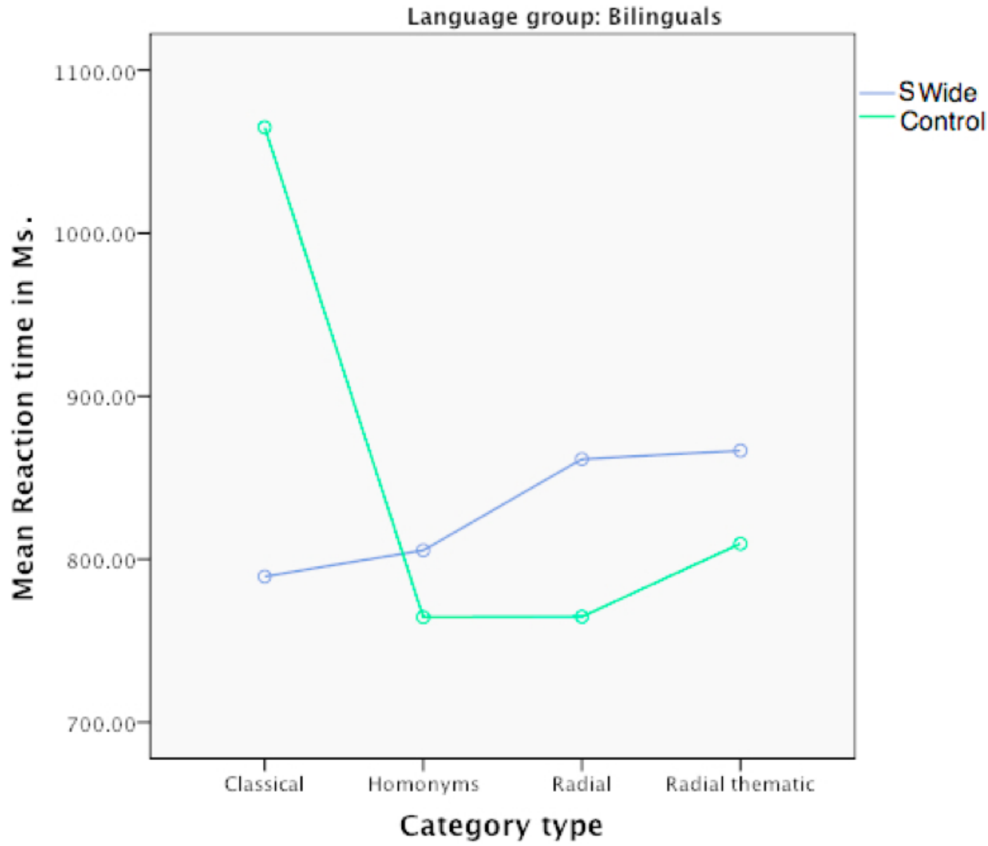


Figure 6.2. Mean reaction times in the s_wide and control conditions across categories in bilinguals

Monolingual Group

A separate analysis of the monolingual group revealed a significant effect of Category type, $F(3,51)=2.98$, $p<0.05$. Pairwise comparisons between category types revealed that reaction times for classical category times were slower than homonyms, radial taxonomic and radial thematic categories ($p<0.05$). Furthermore, reaction times for radial thematic categories were significantly slower than for homonyms ($p<0.05$). There was an interaction of Category type by Condition, $F(1,17)=12.07$, $p<0.01$, showing that reaction times for classical categories in the s_wide control condition were slower than in the control condition($p<0.05$). There were no significant differences between s_wide and control conditions in homonyms and radial categories, see figure 6.3.

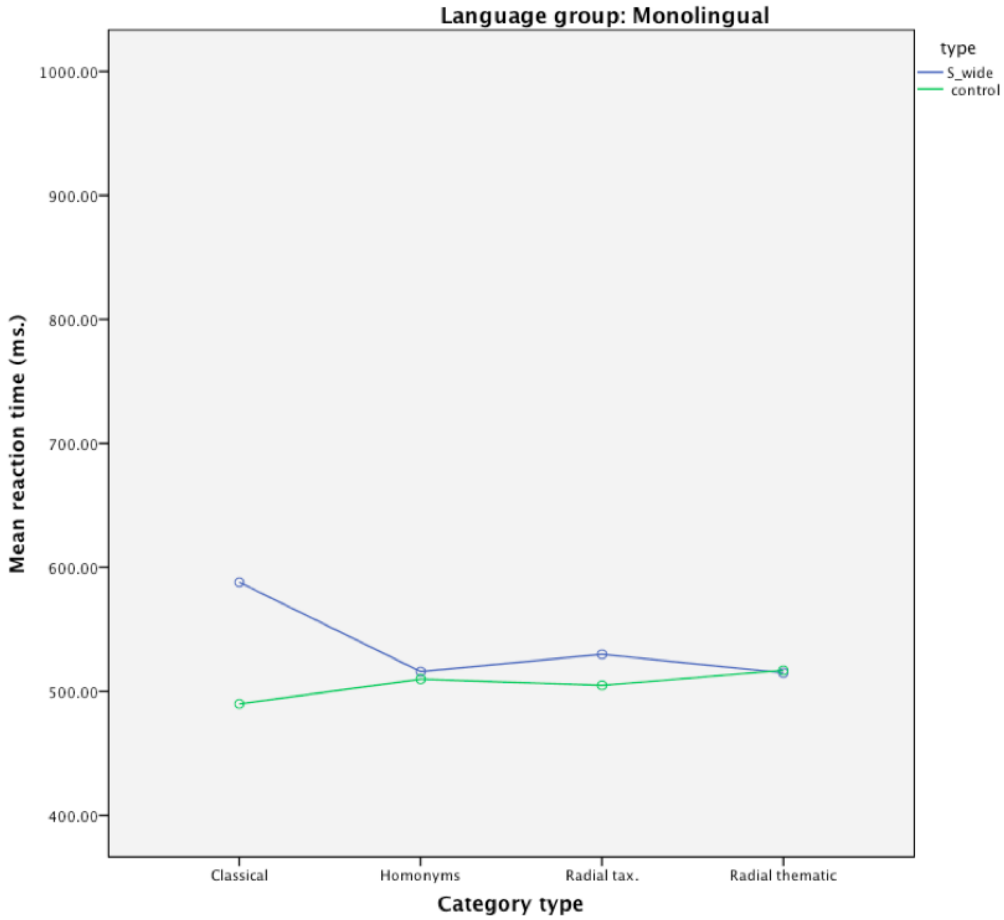
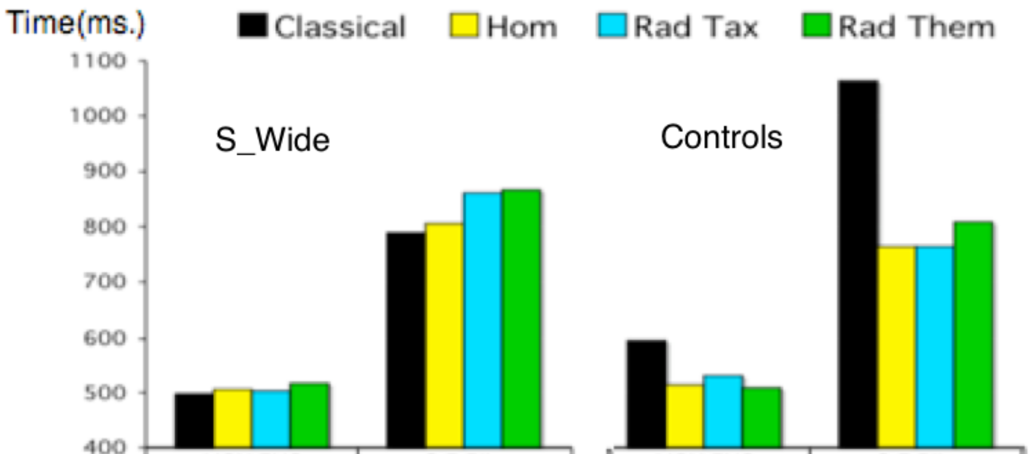


Figure 6.3. Reaction times in the s_wide and control conditions across categories in monolinguals

Summarizing, reaction times for the bilingual group were slower in all category types (mean Spanish =840.75 ms., mean English = 521.67 ms.) and classical categories were processed slower in both language groups. Differences in reaction times for s_wide and control items were also largest in classical categories for both language groups, although there were different patterns in each language group: in bilinguals, classical categories in the s_wide condition were processed faster than in the control condition, while radial thematic categories showed an inverse pattern (slower reaction times in the s_wide than in the control condition).

In the monolingual group, classical categories in the control condition were processed faster than classical categories in the s_wide categories. Additionally, the differences between s_wide and control stimuli were considerably higher in the bilingual Spanish group (275 ms.) than in the monolingual English group (98 ms.).

Finally, in the bilingual Spanish group, reaction times for radial thematic categories were significantly slower than homonyms ($p<0.05$), see figure 6.4.



	S_Wide MON ENG	S_Wide S-E BIL	Controls MON ENG	Controls S-E BIL
Classical	497.6	789.4	595.6	1064.8
Hom	506.9	805.4	513.5	764.4
Rad Tax	502.7	861.4	531	764.7
Rad Them	517.1	866.5	509.9	809.4

Figure 6.4: Comparison of reaction times for the bilingual Spanish and the monolingual English groups in s_wide and control categories. Mean reaction times are displayed below the graph

6.4 Discussion

This study aimed at examining whether bilinguals and monolinguals differed in their processing of classical, homonymic and radial categories on a mixed indirect priming task using a long SOA, and which required participants to perform a lexical decision task on both prime and target words.

The results showed that, consistent with the bilingual literature, reaction times of the bilingual Spanish group were slower overall. However, in the bilingual group, classical categories in the s_wide condition presented faster reaction times than in the control condition. The opposite effect was observed for radial thematic categories (faster RT in the control than in the s_wide condition), although in this case, the difference in RT between conditions was much smaller than in classical categories. In the monolingual group, a comparison of s_wide and control items showed that classical categories in the s_wide condition were associated with significantly slower reaction times than classical categories in the control condition –the inverse of the pattern shown by the bilingual group-.

Classical Categories

It was predicted that in the bilingual group, classical categories in the s_wide condition would be processed faster than in the control condition, while no differences between conditions in the monolingual group were expected.

Contrary to our predictions, in the bilingual group, rather than classical categories in the s_wide condition being processed faster, it was classical categories in the control condition that were processed considerably slower than any other category type in the task. Additionally, in the monolingual group, there were unexpected differences between the s_wide and control conditions, specifically, items in the s_wide condition were processed slower than those in the control conditions.

A possible explanation to this phenomenon is that, the bilingual group might be accessing word forms, but not conceptual knowledge in any of the conditions, except for the classical categories. Homonym items in the control condition might appear as completely unrelated to the bilingual speakers, while the relation between meanings in radial categories might pass unnoticed. However, the relationship between the two meanings of classical categories is more obvious, so there is a possibility that inhibition is present in classical categories in the control conditions (when there is no common word form accessed). In the case of the monolingual group, it can be argued that the differences observed could be associated to differences of co-occurrence between the s_wide and the control condition, but at the present moment, more research is needed to confirm this hypothesis

Homonyms

Homonym items in the s_wide condition were predicted to be associated with faster reaction times than in the control condition in the bilingual Spanish group, but not in the monolingual English group. The results matched the predictions in case of the English monolingual group (no significant differences between s_wide and control items). However, results from the bilingual Spanish group diverge from the predictions, since there were no significant differences between s_wide and control items in reaction times although reaction times for homonyms in the control condition were marginally faster than for s_wide items.

There are three possible explanations to why no differences between conditions were found in homonym category items. The first possible cause might be that the differences between s_wide and control items are too subtle to be detected by an explicit (conscious, i.e. not using masked primes) behavioural study, the second explanation is that it might be that the bilingual Spanish speakers are not accessing the L1 word forms, but only access conceptual information (as it is hypothesised that it happens with classical categories in the control condition). A third explanation, and perhaps the most plausible, is that Spanish speakers are actively inhibiting L1 lexical representations in the task, which would partly explain why s_wide items (related) are slower, consistent with the notion that inhibition implies additional effort that adds-up to the cognitive cost of the task. In any case, these results support the hypothesis that classical categories and homonyms are processed differently.

Radial categories

As predicted, there were no differences between conditions in the monolingual group, while there were differences between conditions in the bilingual group. It was predicted that in the bilingual group, items in the s_wide condition would be processed faster than items in the control conditions. However, the results showed a different pattern: both radial taxonomic and radial thematic categories were processed faster in the control than in the s_wide condition, although only in the cased of radial thematic categories the difference was significant. While this result might seem odd initially, radial thematic categories showed differences from the rest of categories the previous chapter in that performance was lowest in the "narrow" condition. Furthermore, processing of radial thematic categories was not affected by the presence or absence of a linguistic label. The results about radial thematic categories from the previous and the present chapter suggest that L1 information might be active during the task, and that inhibition of L1 information involves increased cognitive load, which is reflected in slower reaction times.

Implications For The Relationship Between Language And Thought

The present results suggest that the relationship between linguistically mediated and non-linguistically mediated categories is modulated by the type of category. In classical categories, there was interaction between the lexico-semantic and conceptual systems: performance in the lexical decision task was best when both systems were congruent, that is, when the boundaries of the semantic category and the conceptual category were the same (lexicalized, S_wide categories), such as in *finger-toe,* (which are the same conceptual /taxonomic category and the same semantic category in Spanish). When the boundaries of the semantic and conceptual categories differed, such as *elbow* and *knee,* which are of the same conceptual/taxonomic category similar, but not the same semantic category (In Spanish: *codo* and *rodilla* respectively), reaction times were higher than in S_wide categories. We speculate that higher reaction times might be due to effects of inhibition or to the participants attempting to integrate (in the same reference frame) two apparently unrelated meanings.

In the processing of homonyms, as mentioned in the previous chapter, the role of the conceptual system appears to be lesser than in classical and radial categories, given that there is no conceptual relationship between primes and targets.

Regarding radial categories, the results support the hypothesis of interaction between the lexico-semantic and conceptual systems. Specifically, access to L1 semantic and conceptual systems might take place, but when between prime and target are members of the same conceptual and semantic category (S_wide), reaction times were slower, which indicates a potential effect of inhibition or an increased cognitive cost when accessing both semantic and conceptual systems. However the nature of the behavioural measures used in the present study does not allow us to rule out a potential access to L1 in bilinguals when processing categories that are lexicalised only in the L1. This issue will be addressed in the ERP study, presented in the next chapter.

Chapter 7

ERP Priming Study

7.1 Introduction

The studies previously reviewed in this thesis have used behavioural measures to explore the relationship between the semantic and conceptual systems in late Spanish-English bilinguals, compared to native English monolinguals. In the fifth chapter, classical, homonymic and radial categories were examined in a category membership judgement task and in the sixth chapter, the different category types were examined in an indirect priming paradigm that used a lexical decision task. The present study builds upon the previous research, by examining the time course of ERP and topographical distribution components in a delayed semantic decision task performed by monolingual English and late bilingual Spanish-English participants. The present study used written word pairs corresponding to classical, homonyms, radial taxonomic and thematic categories, as well as unrelated word pairs.

Behavioural measures, as employed in the study outlined in the fifth chapter provided information of the transfer of category boundaries from L1 (Spanish) to L2 (English), while the sixth chapter provided information on semantic priming effects within category types. Semantic priming effects, hypothesised to be due to semantic relatedness in the L1 were also shown while performing a lexical decision task in the L2. This effect could be taken as an indicator that, when reading an L2 word, the corresponding L1 translation was activated, and additionally activation is spreading to concepts that are related to the L1 translation, but that are unrelated in the L2. However, some authors have pointed out that brain processes involved in the retrieval of semantic information during language comprehension are too subtle to be detected using behavioural techniques (Kutas & Federmeier, 2000).

The process of language comprehension has been assumed to be divided in lexical and a post-lexical stages (Fodor, 1983, Swinney, 1991). The lexical stage involves recognition of the word, and is a fast and automatic process, which is affected by word properties such as word frequency, number of orthographic neighbours. On the other hand, the post-lexical stage receives input from the lexical process and integrates it in the linguistic context. The post-lexical process is affected by the linguistic context (i.e. predictability) and congruence with the overall discourse (Hagoort et al., 2004).

Given that lexical processing occurs automatically, authors have argued that lexical processes are "elusive" to behavioural measures, and that behavioural measures, especially paradigms registering reaction times are more sensitive to the detection of post-lexical effects (Klepousniotou, et al. 2012). Additionally, semantic priming studies using reaction times have been criticised because they require the participants to engage in an additional task –making a behavioural response- besides lexical processing, thus confounding the contributions of both processes in the observed priming effect (Neely et al., 1989)

By examining brain activity, one can overcome some of the limitations in lexical processing studies that use behavioural measures. The voltage generated by brain activity (brain activity observed at the scalp) has been assumed to originate in two sources: action potentials, which are voltages travelling from the axon to the body of the neuron, and postsynaptic potentials, which are changes of voltage in cell membrane, caused by the incorporation of neurotransmitters to postsynaptic receptors (Stemmer & Whitaker, 2008) The electrical activity generated by postsynaptic potentials can be measured at the scalp using EEG (electroencephalogram) techniques, which provide a very high temporal resolution. However, rather than examining the raw signal recorded at the scalp (EEG), research in language has focused on ERP (event related potential) components (Kutas & Federmeier, 2000). ERP components are voltage potentials recorded at the scalp, which reflect neurocognitive processes associated with sensory, cognitive and motor events. ERP components are extracted from the raw EEG data and averaged across stimuli (Luck, 2005).

In particular, the N400 component, a large negative deflection that is present in the 200-600 ms. time window (peaking around 400 ms.), and largest over central-parietal sites has long been seen as an important tool for the study of language. In a series of studies, Kutas & Hilyard (1980), used a paradigm where the last word of a sentence was manipulated, in order to produce sentences with a congruent ending ("I shaved off my moustache and beard"), an improbable ending ("He planted string beans in his car") or incongruent ending ("I take coffee with cream and dog"), the authors found larger amplitude N400 effects associated with incongruent and anomalous sentences, compared to congruent sentences (Kutas & Federmeier, 2011). It was later shown that the N400 component is not only present in sentence contexts: N400 effects were observed in semantic priming contexts were the degree of relation (semantic, associative or phonological) between a prime and a target word was manipulated (Kutas & Van Petten, 1988). Furthermore, The N400 component has been shown to reflect lexical-semantic processing, Rodd, et al. (2002), found facilitation effects in a lexical decision task using words with multiple senses (polysemous words), while performance was slowed for ambiguous words (homonyms). The authors argued that homonymic words are connected to different representations of meanings in the lexicon, and the disadvantage associated with processing homonyms could potentially reflect competition for activation of the different meanings of homonymic words. On the other hand, polysemous words are assumed to map onto a single mental representation with the extended senses of the word are created from the basic sense by means of lexical rules. Klepousniotou et al (2012) found smaller N400 amplitudes for the dominant (high frequency) meanings of polysemous words, and higher N400 amplitudes for both senses (dominant and subordinate) in homonyms.

The findings regarding differences in N400 amplitudes raise the question of whether there are N400 differences in the processing of the stimuli used in the present research. Specifically, homonyms and classical categories differ in the fact that homonyms consist of two separate lexical entries (separate meanings), while classical categories share a common superordinate category, so that hypothetically, smaller N400 amplitudes could be expected for classical categories than for homonyms. Regarding radial categories, it remains unclear whether the difference in the type of relation between the central and the extended senses could give rise to differences in N400 amplitude between radial categories with thematic links and radial categories with taxonomic links.

Predictions

In the comparison of related and unrelated controls, a larger N400 amplitude is expected for unrelated stimuli in comparison to related stimuli in both language groups, consistent with the notion that the N400 effect reflects the level of semantic integration of words (Kutas & Federmeier, 2000).

Classical categories will be compared to related controls, so that in monolingual speakers, the fact that the classical categories used were not lexicalised in English would be reflected in a larger N400 effect (if lexicalisation = more relatedness) than the related controls. On the other hand, no differences between related controls and classical categories are expected in the bilingual group if there is access to L1 (Spanish) category structure (boundaries)/lexicalisation while performing the task in the L2 (English). If no access to L1 category information is involved, bilinguals are expected to exhibit a pattern similar to that of the monolingual group.

Homonyms will be compared to unrelated controls. In the monolingual group, no differences between homonyms and unrelated controls are expected, since the homonyms shared the same lexical form only in Spanish. However, if access to L1 (Spanish) occurs in the bilingual group when processing stimuli in their L2 (English), larger N400 amplitude is expected for unrelated controls than homonyms in the bilingual group. If bilingual participants perform the task without accessing their L1, then no differences between homonyms and unrelated controls would be expected.

Finally, radial categories will be compared to related controls. Monolingual participants are expected to show a larger N400 amplitude for radial categories than for related controls (since radial categories are not lexicalised in English). In the bilingual group, if access to L1 category structure when performing the task in their L2, no differences would be expected in N400 amplitude between related controls and radial categories. However, if no L1 access is involved in the task, then larger N400 amplitudes would be expected for radial categories than for related controls).

7.2 Method

Participants

Twelve Spanish L1, English L2 late bilinguals (nine female, three male), aged 29-58 (mean =35.83) and fifteen native English monolinguals (ten female, five male), aged 22-32 (mean =24.66) took part in the present study. Differences in age between the language groups were significant ($p<0.05$), however, the difference was not deemed to be a problem, given that category comparisons were always within each language groups. All participants were right handed and had normal or corrected-to-normal vision. Participants wearing contact lenses were asked to wear their glasses for the task, in order to avoid eye blinks. Participants in the bilingual group reported to have learned English after 12 years of age, to have at least five years of experience in speaking English, and at least three years of living in Great Britain and using English as their main everyday language. Participants were recruited in Bangor, North Wales, U.K. and were paid £7 for their participation in the study (a testing session lasted approximately an hour).

Stimuli

The stimuli used in this study were s_wide, related control and unrelated control categories. As with the previous behavioural studies, s_wide stimuli and related controls were divided into classical, homonyms and radial categories. In total, there were 20 s_wide classical categories, 20 s_wide homonyms, 20 s_wide radial categories, 20 related controls and 20 unrelated controls. Each word pair was presented twice: first in the word1 – word2 order, and then in the word2 – word1 order (see appendix 6).

Procedure

Participants performed the task while sitting in an armchair, in a faraday-cage room. A 46 inch LCD screen with a resolution of 1920 x 1080 pixels and a refresh rate of 60 Hertz was used to display words in white letters on a black background, using a 48 pixel font. Participants sat 120 cm from the screen.

Participants performed a delayed semantic decision task where they were required to respond 'yes' or 'no' to the question of whether each of the items denoted by the words would fit in a typical shoebox. Specifically, the experimenter gave the following instructions: "do each of these things fit in a shoebox separately ?, that is if given two shoeboxes, could each of these items fit in one shoebox?". Participants were instructed to read the two words and to press a button only when the response screen was presented. Additionally, blinking was allowed during the response screen. All instructions were in English, although Spanish was used when welcoming Spanish speakers to the experiment.

Each trial started with the presentation of a fixation cross for 500 ms., followed by the first word (500 ms.), a fixation cross, which was presented for a jittered period of time (300 to 900 ms.), then the second word was presented (500ms.) and a fixation cross (500 msec.) A response screen showing the words "yes or no" then appeared until participants made a response by pressing a button on a serial controller box with three buttons (yes/no/unsure). For half of the participants, the 'yes' button was located on the right of the controller box, while the 'no' button was located on the left. This arrangement was reversed for the other half of the participants. The 'unsure' button was always located in the middle and below the 'yes' and 'no' buttons.

The duration of the experiment was of approximately 20 minutes, and consisted in four runs of five minutes, with a brief pause in between runs. Half of the participants were assigned to version A, and the other half to version B.

EEG Data Acquisition

EEG recordings were digitized continuously throughout the experiment via pin-type Ag-AgCl active electrodes attached to a cap (BioSemi headcaps). Electrodes were placed in 64 standard scalp positions over the frontal, fronto-central, temporal, parietal, and occipital regions of the left and right hemispheres. In addition, electrodes were also placed under and over the eye in order to monitor eye movements, so trials with blinks or vertical eye movements could be excluded or corrected from analyses. EEG recordings were amplified using a Bio-Semi EEG system and sampled every 0.5 ms. Filtering was conducted offline with a band pass of 0.01 Hz to 30 Hz. Recordings were performed reference free.

ERP Data Analysis

Data were analysed in EEGLAB 9.0.8.6b (Delorme & Makeig, 2002) and ERPLAB 1.0.0.33 (Luck & López-Calderón), running on Matlab 2009b (Mathworks Inc.). Data for each participant were first filtered with a band pass IIR butterworth filter (0.01 to 30 Hz) and then, the EEG data was re-referenced to the signal average of the left and right mastoid electrodes. Manual removal of large artifacts (drift, muscular movement) was performed, and in order to remove ocular artifacts, an ICA decomposition was performed using the runica algorithm (available in EEGLAB), and data were re-constructed omitting the eye-blink component. After pre-processing, data were segmented in 1000 ms. Epochs (starting 200 ms. Before the presentation of the second word and ending 800 ms. after). Baseline correction was performed using a 200 ms. time window. ERP averages were computed for all five conditions (related controls, unrelated controls, classical, homonymic and radial categories). Since the component of interest to the present study was the N400, the mean amplitude between 400 and 600 ms. was taken as a measure of the N400 effect.

In order to address the experimental questions regarding differences in category types, repeated measures ANOVAS were computed for four comparisons between category types: a) related minus unrelated, b) classical minus unrelated, c) homonyms minus unrelated controls, and d) radial minus related.

7.3 Results

Comparison of Related and Unrelated Controls

Related and unrelated control word pairs were assumed to be processed similarly in the monolingual and bilingual group, since these were not lexicalised in Spanish or in English (although as mentioned earlier, the bilingual group performed the task in their L2, whereas the monolingual group performed the task in their L1). In order to simplify the process of analysis, a subset of 24 electrodes was used. Electrodes were distributed in four regions: left anterior, left posterior, right anterior and right posterior (see figure 7.1)

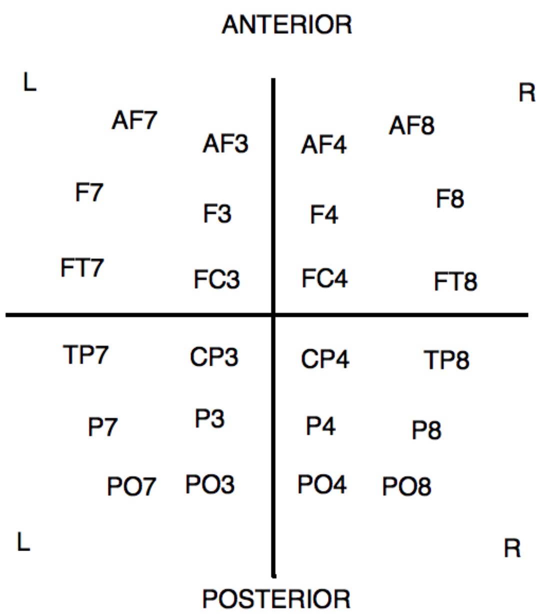


Figure 7.1: Electrode distribution by region and site, as used in the analysis of related and unrelated controls

For each language group, a repeated measures ANOVA was performed, using three within subject factors: category type (related, unrelated) region (left anterior, left posterior, right anterior, right posterior), and electrode (with six levels, where each level corresponded to an electrode). The results are divided by each language group in the following sections.

Monolingual participants

The analysis revealed no main effects of category type. However, there was a two way interaction effect of Category Type x Electrode, $F(5,55)=2.928$; $p < 0.05$, and a three way interaction of Category Type x Region x Electrode, $F(15, 165) = 2.040$, $p<0.05$. Post hoc analyses revealed that were differences in p400 mean amplitude between related and unrelated stimuli in all electrodes, except a small number of electrodes in the left frontal region: AF7 ($t_{11}=0.309$; $p=0.763$) and F3 ($t_{11}=2.097$; $p=0.063$), right frontal region: AF8($t_{11}=0.922$; $p=0.378$), AF4 ($t_{11}=1.898$; $p=0.084$) and in the right posterior region, PO8 ($t_{11}=1.013$; $p=0.333$), see figure 7.2.

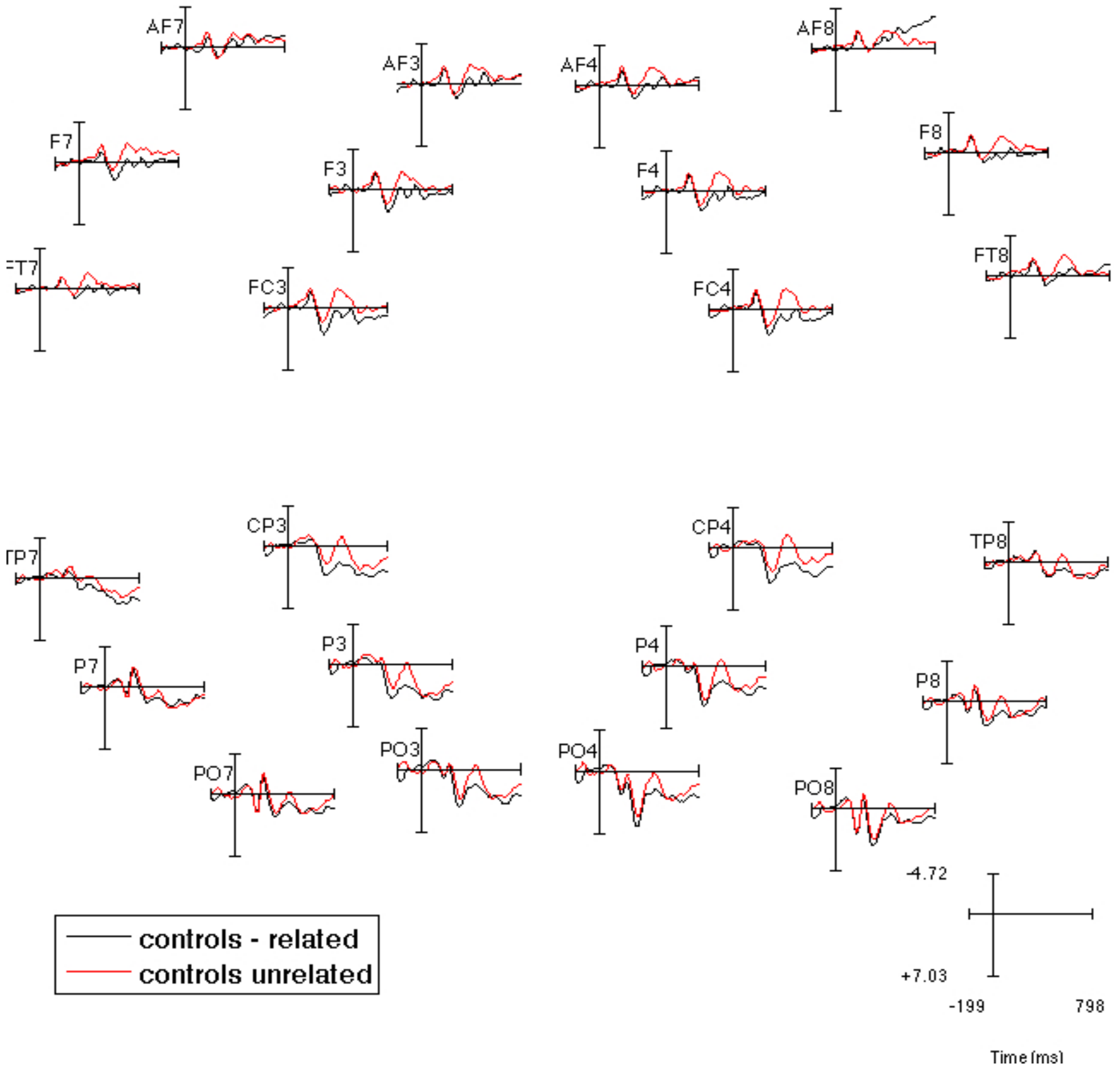


Figure 7.2: Comparison of averaged data for related and unrelated controls in the monolingual group.

Bilingual participants

In the bilingual group, there was an effect of Category Type, $F(1,10)=7.053$, $p<0.05$. Post-hoc analyses revealed differences between unrelated and related categories in all electrodes, except several electrodes in the left frontal region: AF7 ($t_{10}=-0.156$; $p=0.879$), F5 ($t_{10}=-0.842$; $p=0.419$), F3 ($t_{10}=-0.183$; $p=0.859$), AF3 ($t_{10}=1.147$; $p=0.278$) and in the right frontal region: AF4 ($t_{10}=0.526$; $p=0.610$) and F8 ($t_{10}=0.325$; $p=0.752$), but not in posterior regions. See figure 7.3.

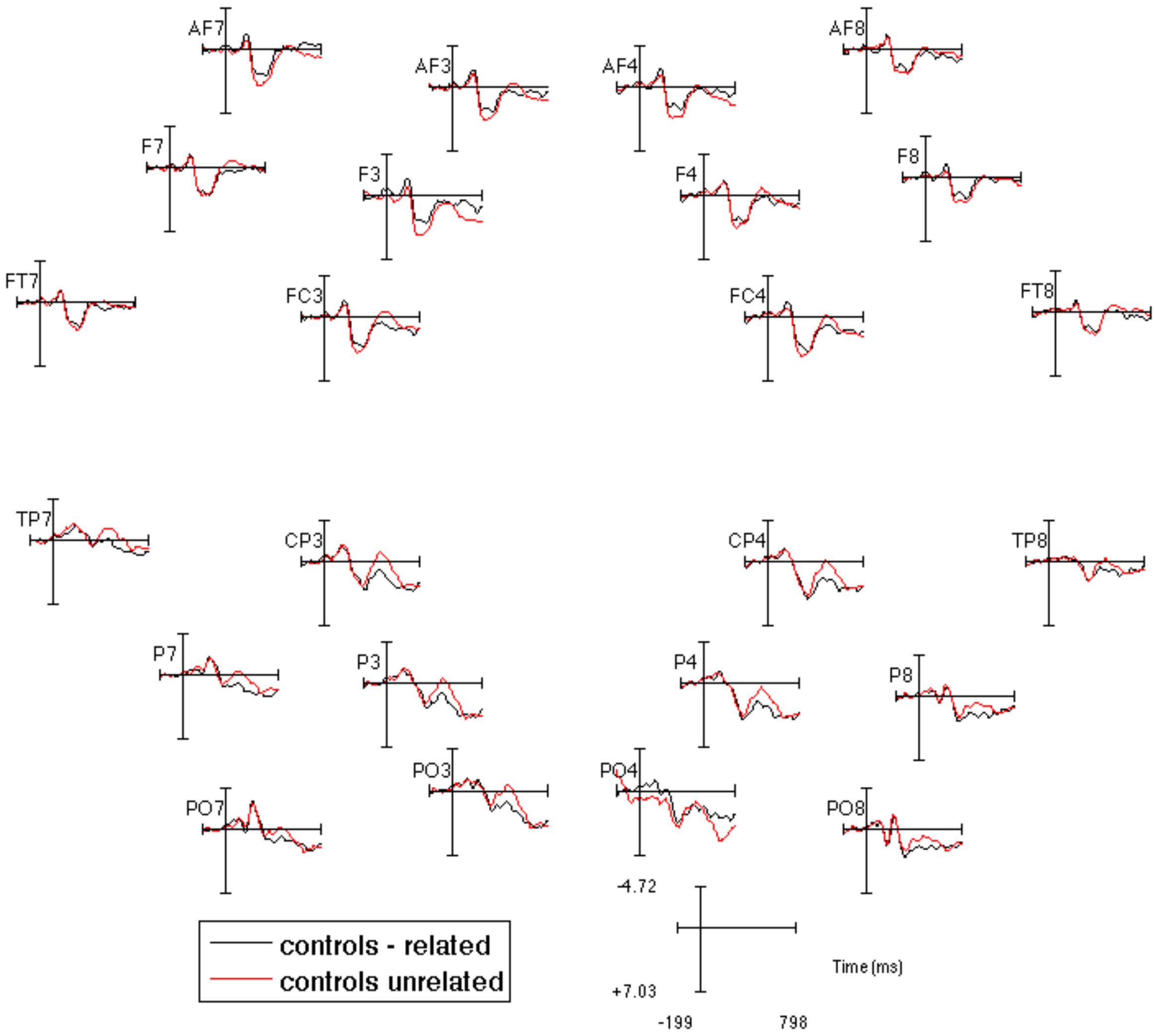


Figure 7.3: Comparison of averaged data for related and unrelated controls in the bilingual group.

Topographic distribution of difference waves

Difference waves for unrelated control minus related control conditions were computed for each language group. The topographic distribution of difference waves of each language group showed, as expected, predominantly larger N400 amplitudes for unrelated than related controls. Additionally, while in monolinguals, significant differences in N400 amplitude between related and unrelated controls were shown across most of the scalp, in bilinguals, differences occurred predominantly in central and posterior regions, while frontal regions showed a tendency towards no differences between related and unrelated controls (see figure 7.4).

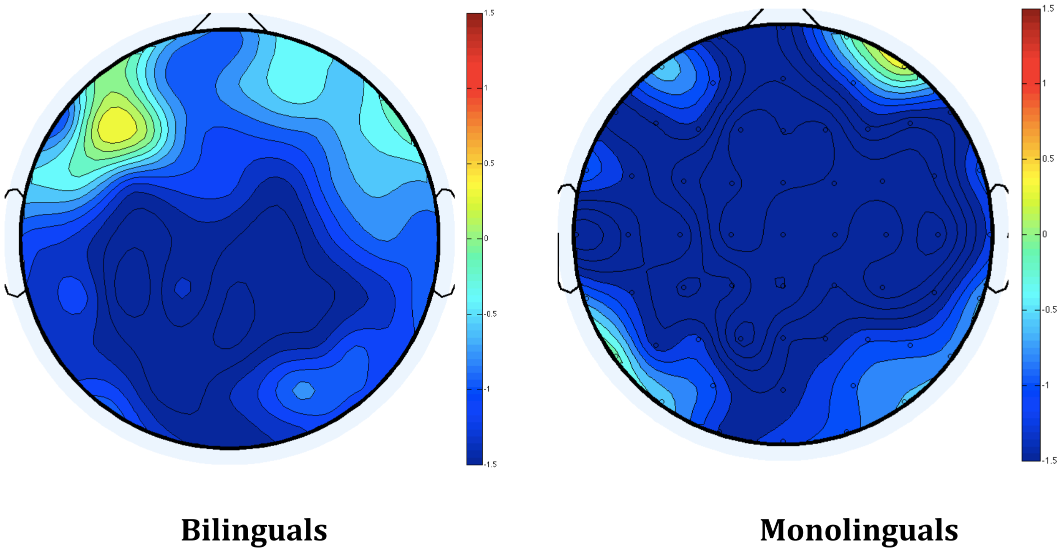


Figure 7.4: topographic distribution of the [unrelated controls – related controls] difference wave for bilinguals and monolinguals.

Comparison of Classical Categories and Related Controls

Monolingual group

A plot of the averaged ERP data of the monolingual group suggested possible differential mean amplitude differences for the N400 effect in most electrodes, but especially in P1, Cp1, Cp3, P7, Pz, POz, Oz, Cp2 and C2, See figure 7.5. To examine whether these differences were statistically significant, a repeated measures ANOVA with two factors, category type (classical, related control) and electrode (nine levels, one for each electrode) was performed. The analysis revealed a main effect of category type F (1,11) = 9.501, p <0.05, and no interaction effects. Post hoc analyses revealed differences by category type in P1 (t_{11}=3.749; p<0.01), Cp1 (t_{11}=2.776; p<0.05), Pz (t_{11}=2.766; p<0.05), POz (t_{11}=3.576; p<0.01), Cp2 (t_{11}=3.110; p<0.05) and C2 (t_{11}=2.320; p<0.05).

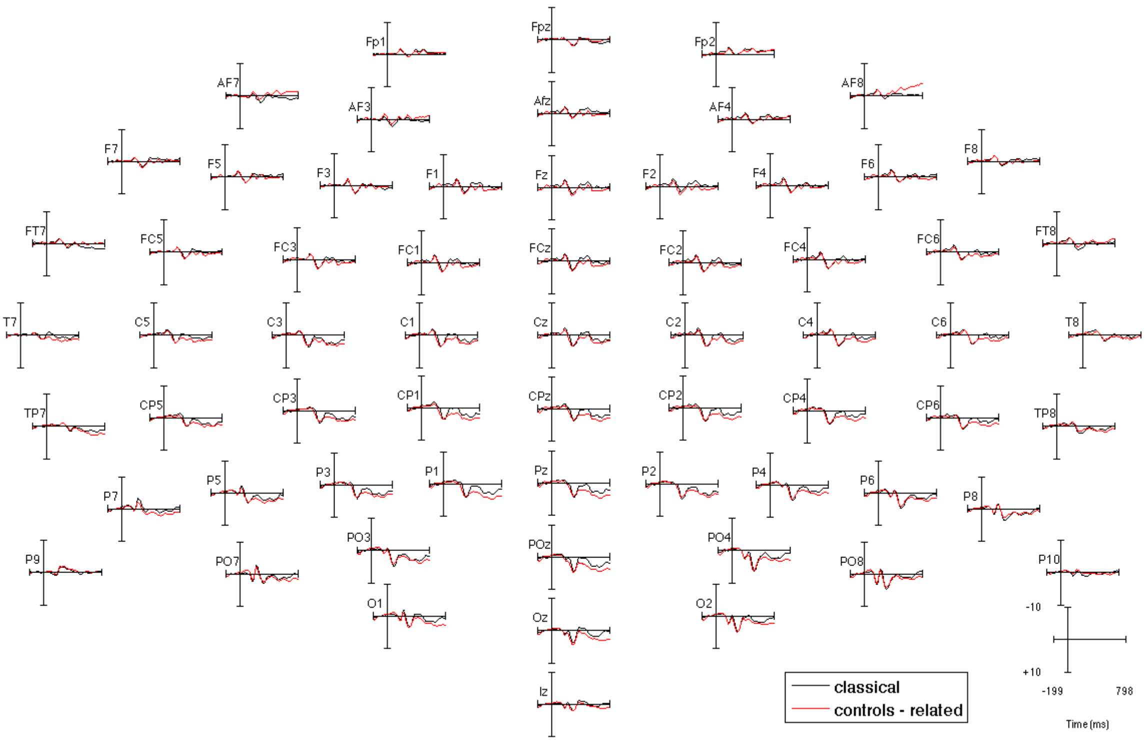


Figure 7.5: Comparison of averaged data for classical categories and related controls in the monolingual group.

Bilingual group

The averaged ERP data in the bilingual group did not show potential differences by category type in electrodes, except for F8, (see figure 7.6). In order to examine whether there were no differences in N400 mean amplitude in classical categories and related controls, a repeated measures ANOVA was calculated, using the same electrode subset that was used in the comparison of related and unrelated controls. The analysis revealed no effects of category type, $F\,(1,10)=0.05$, $p=0.945$.

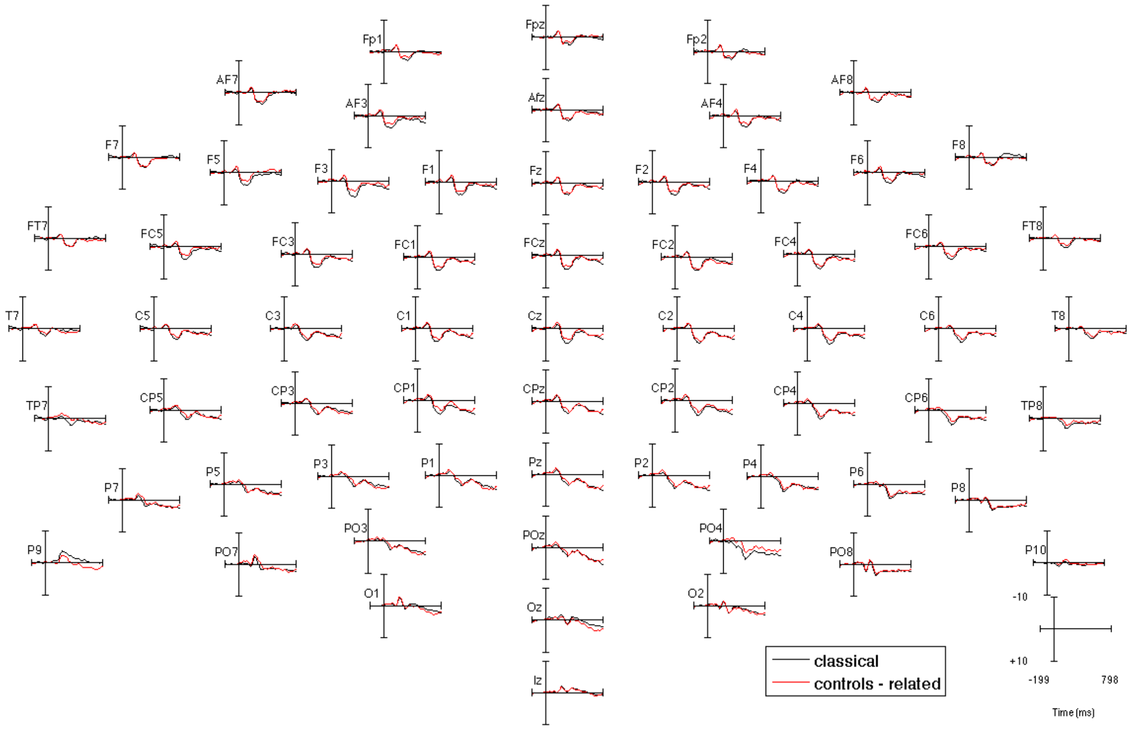


Figure 7.6: Comparison of averaged data for classical categories and related controls in the bilingual group.

Topographic distribution of difference waves

There were differences in the distribution of the classical categories minus related control difference waves (see figure 7.7). In the monolingual group, classical categories were associated with a significantly larger N400 amplitude than related controls in most electrodes, consistent with the fact that the classical categories used are not lexicalised in English. However, in the bilingual group, there were no significant N400 amplitude differences between conditions.

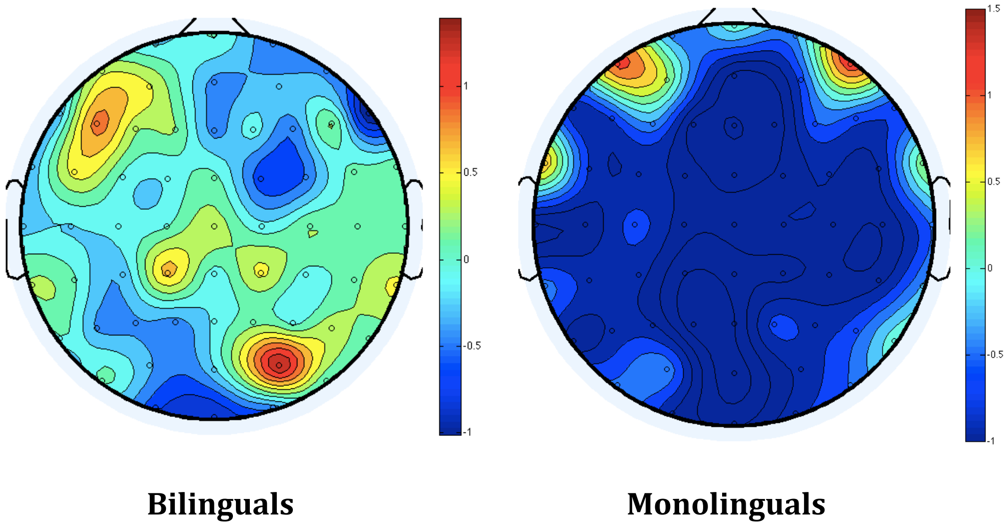


Figure 7.7: Topographical maps of the classical-related difference wave in the monolingual and bilingual groups.

Comparison of Homonyms and Unrelated Controls

Monolingual group

In the ERP average of the monolingual group, two electrodes (P1 and Ft8) showed potential differences in N400 amplitude for homonyms and for unrelated controls (see figure 7.8). However, a repeated measures ANOVA using Category Type (homonym, unrelated) and electrode (P1, Ft8) did not show any significant effects of category type, F (1,11) = 0.55, p = 0.819. There were no interaction effects.

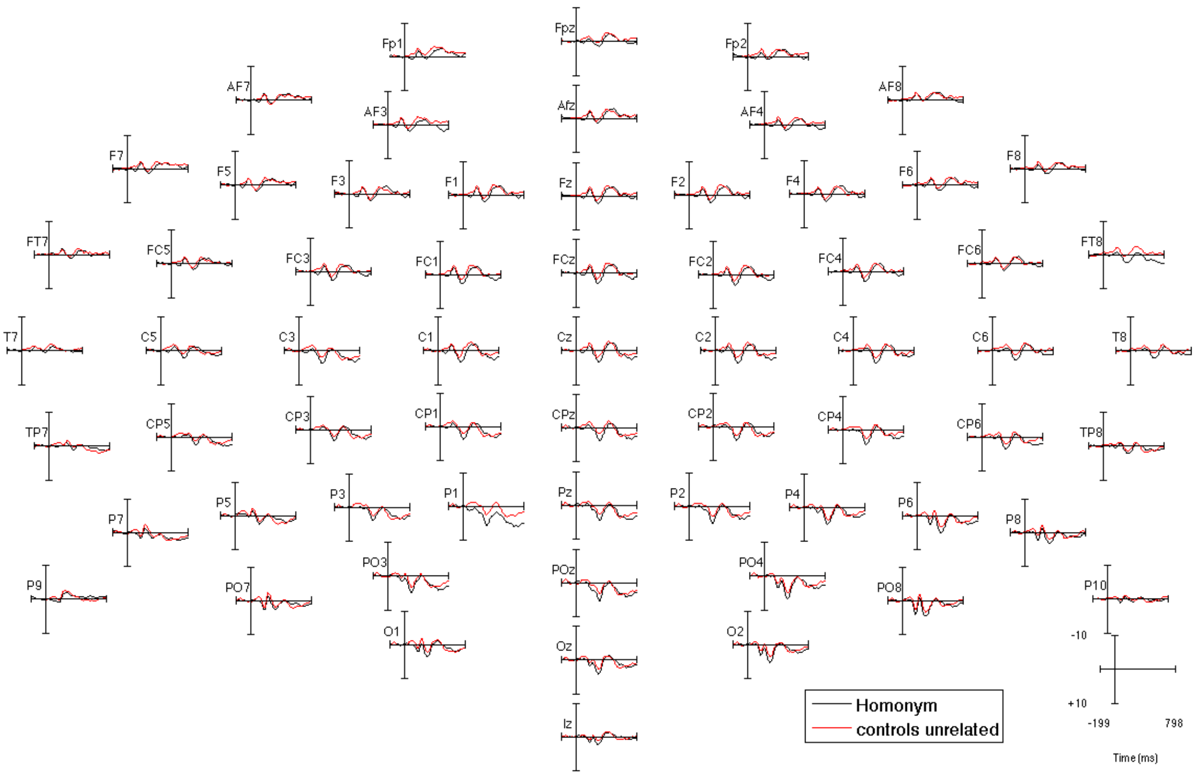


Figure 7.8: Comparison of averaged data for homonyms and unrelated controls in the monolingual group.

Bilingual Group

The ERP average for the bilingual group showed potential differences in N400 amplitude between conditions in Fpz, F7, F5, F3, C3 and TP7 (see figure 7.9). Post-hoc tests revealed significant differences in F7 (t_{10}=-2.381, p=0.039) and a near-significant effect in Fpz (t_{10}=-2.075, p=0.065) and TP7 (t_{10}=-1.969, p=0.77), see figures 7.10

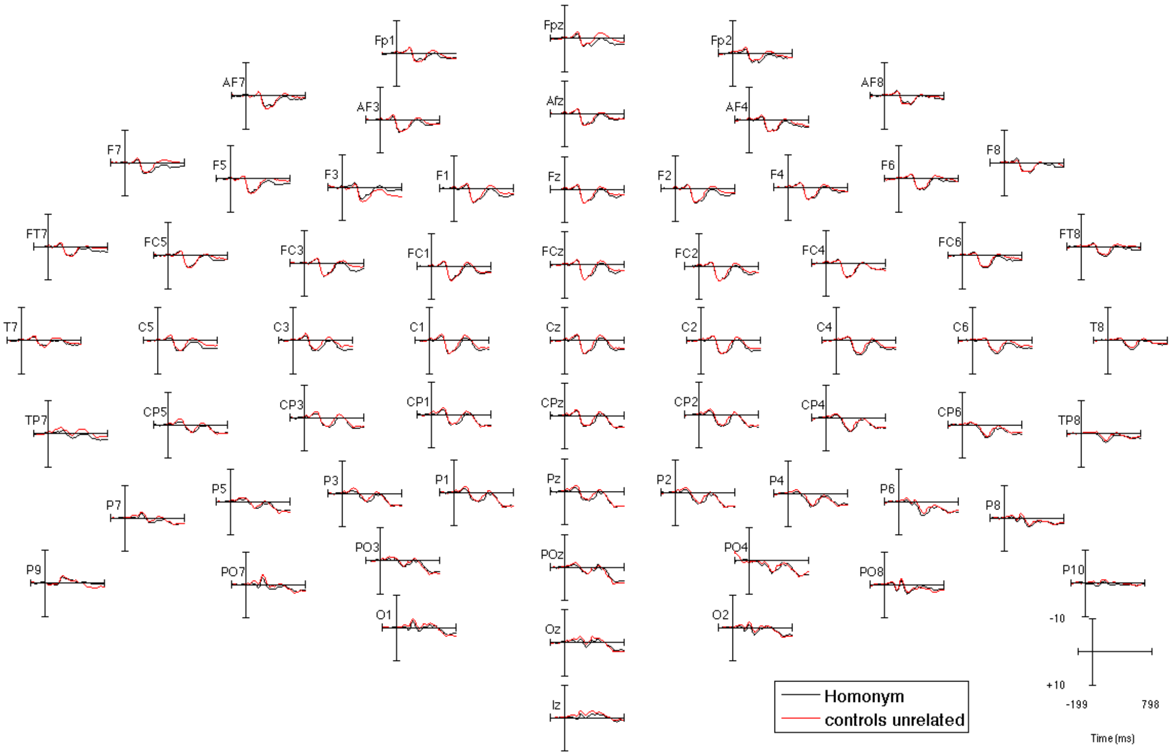


Figure 7.9: Comparison of averaged data for homonyms and unrelated controls in the bilingual group.

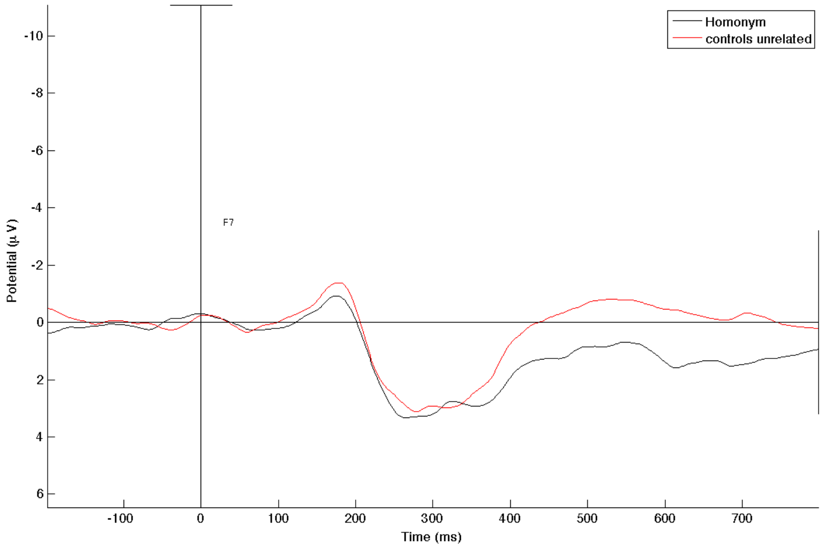


Figure 7.10: Differences in N400 amplitudes for homonyms and unrelated controls in F7

Topographic Distribution of Difference Waves

As predicted, there were no significant differences in N400 amplitude between homonyms and unrelated controls in the monolingual group. In the bilingual group, the N400 amplitude differences were located in the left anterior region, in F7, where unrelated controls were associated with larger N400 amplitude than homonyms. Additionally, the electrodes in the posterior region showed a tendency towards larger N400 amplitude for unrelated controls than for homonyms, although the differences failed to reach significance (see figure 7.11).

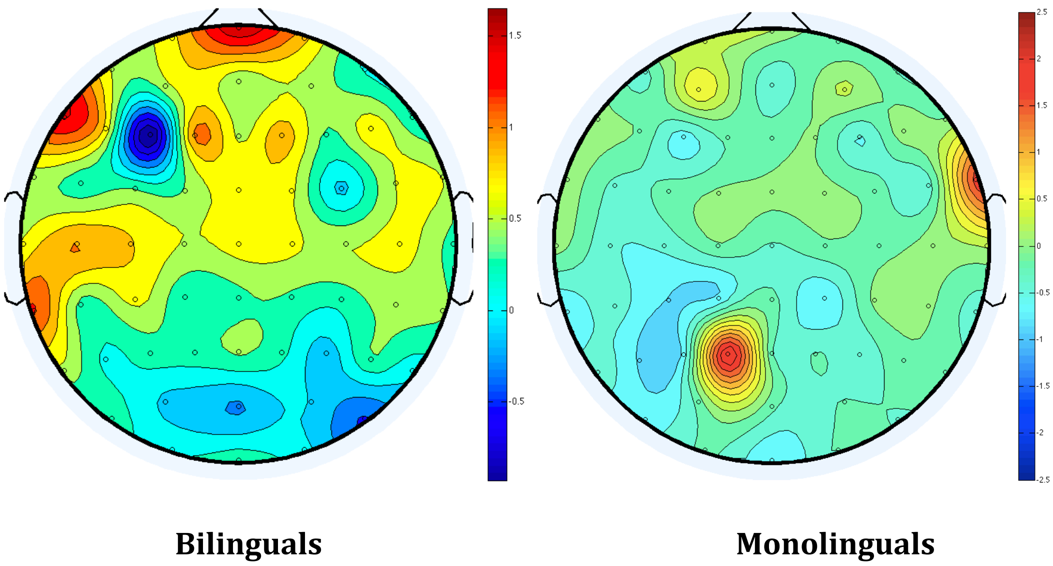


Figure 7.11: Topographical maps of the radials-unrelated difference wave in the monolingual and bilingual groups.

Comparison of Radial Categories and Related Controls

Monolingual Group

The ERP averages of radial categories and related controls for monolinguals showed potential differences between conditions in several electrodes: FP1, FP2, F2, C3, CP3, Oz, CPz, CP2 and CP4. However, a repeated measures ANOVA revealed no main effects of Category Type, F (8,88) = 3.285, p=0.125, see figure 7.12

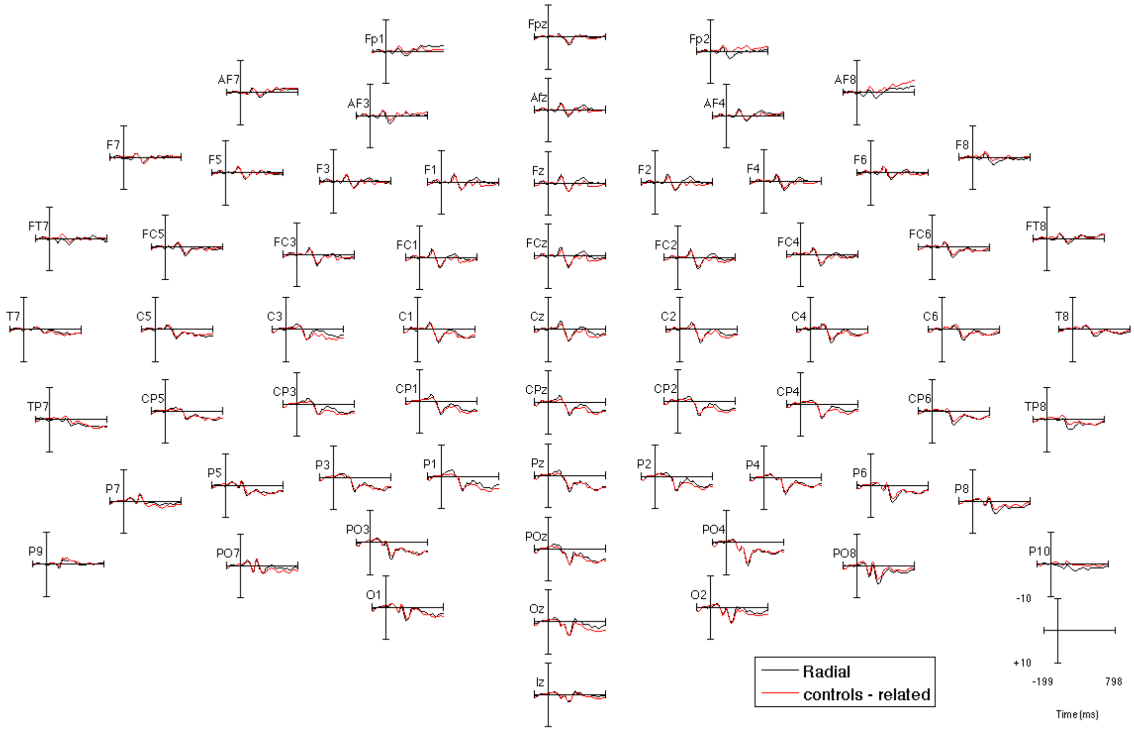


Figure 7.12: Comparison of averaged data for radial categories and related controls in the monolingual group.

Bilingual Group

The ERP averages of radial categories and related controls for Bilinguals showed potential differences by category type in the left posterior region (P9, P7, P5, PO3), in O1 and in the posterior right region in Oz and PO4. A repeated-measures ANOVA revealed an Effect of Category Type x Electrode, *F* $(9,90) = 2.507$, $p<0.05$. Post-hoc analyses revealed significant differences by category type in P9 ($t_{10}=2.391$, $p=0.38$, see figure 7.14), and a near-significant difference in O1 ($t_{10}=2.078$, $p=0.64$). See figure 7.13

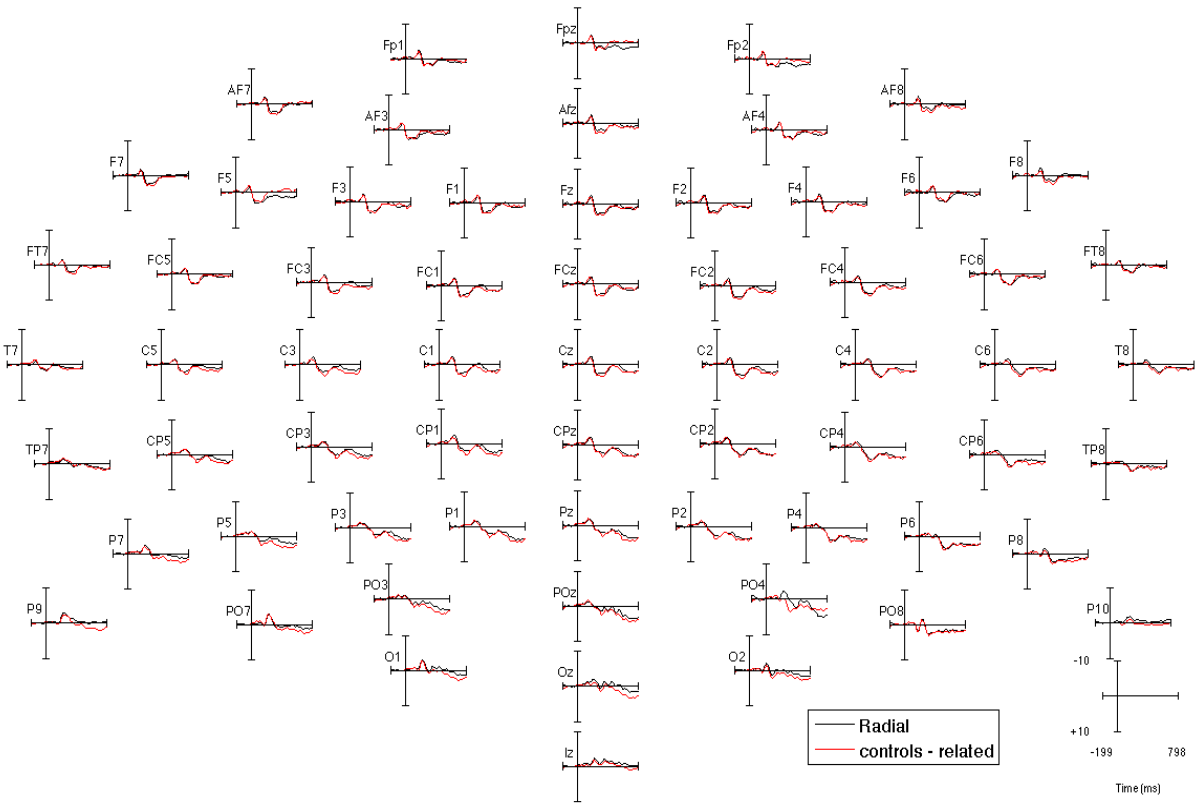


Figure 7.13: Comparison of averaged data for radial categories and related controls in the bilingual group.

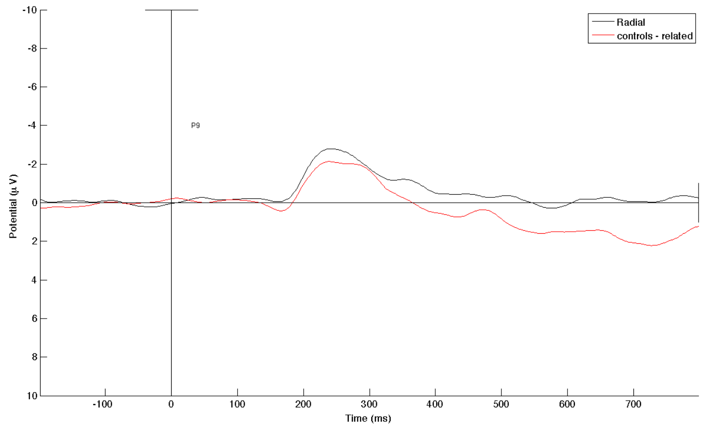


Figure 7.14: Differences in N400 amplitude between classical categories and unrelated controls in P9

Topographic Distribution of Difference Waves

No differences in N400 amplitude between conditions were found in the monolingual group. However, the bilingual group showed larger N400 amplitude for radial categories than related controls in the left posterior region, in P9. There was tendency for larger N400 amplitudes for radial categories than controls in the left and central posterior regions (see figure 7.15)

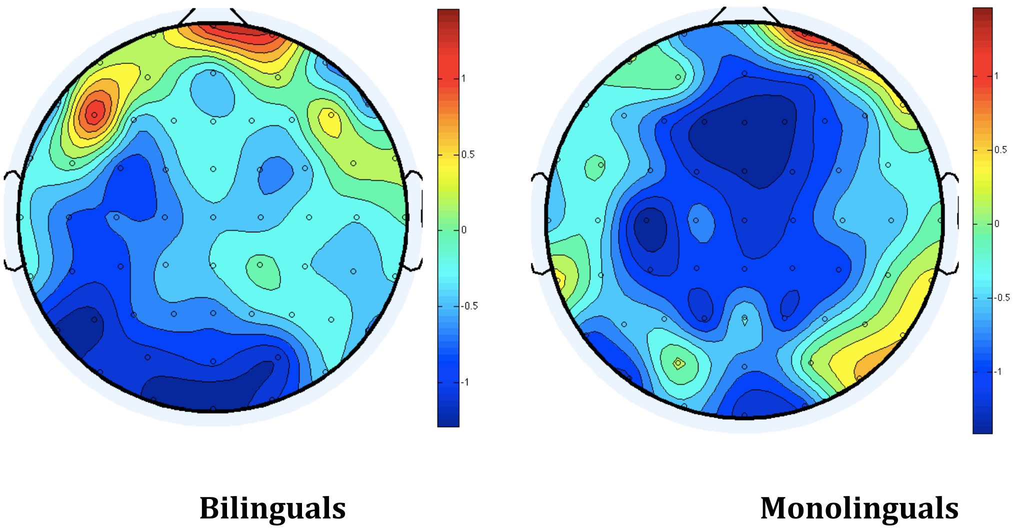


Figure 7.15: Topographical maps of the homonyms-unrelated difference wave in the monolingual and bilingual groups.

7.4 Discussion

The results of the present study confirmed most of the predictions: first, there was an increased N400 amplitude for unrelated, compared to related controls in both bilingual and monolingual language groups. These findings are in line with previous ERP literature, which has reported larger N400 effects for semantically unrelated than semantically related word pairs. Regarding classical categories, monolinguals showed a larger N400 amplitude in classical categories, than in related controls, while in the bilingual group there were no differences between conditions. These results are consistent with the fact that classical categories only "applied" to the bilingual group, or in other words, given that the classical categories used were not lexicalised in English, monolingual participants would have treated word pairs in the classical condition as being "less related" than word pairs in the related controls. However, and as mentioned in the previous experimental chapters, word pairs in the classical category present some degree of conceptual relationship to both language groups, because both words denote objects that belong to the same superordinate category (for instance *finger* and *toe* are both members of the category PARTS OF LIMBS). Nevertheless, the increased N400 effect for monolinguals suggests that the relationship between words in classical categories is less obvious than for related controls. A potential explanation is that, while classical categories share a common superordinate category, related controls are related thematically, such as *paper – pen*.

In the bilingual group, as expected, there were no significant N400 amplitude differences between classical and related stimuli. A plausible explanation for this effect is that, as in the case with classical categories, when bilinguals perform a task in their L2 (English), there is also access to semantic knowledge about L1 category structures or members (or possibly activation of the superordinate member), as well as possibly knowledge of L1 word forms (lexical knowledge). Access to the L1 stores would result in smaller N400 amplitudes for classical categories, and therefore no differences between related controls and classical categories would be shown.

In the third comparison across category types, no differences between homonyms and unrelated word pairs were found in the monolingual group, given that the homonyms only applied to the bilingual group, and for the English speakers in the present study, the meanings of Spanish homonyms would be completely unrelated. In the bilingual group, unrelated controls were associated with larger N400 amplitudes than homonyms in an electrode (F7), although electrodes in the posterior regions showed a similar tendency towards larger N400 amplitudes for unrelated controls than for homonyms. A possible explanation to this phenomenon is that L1 lexical forms in contrast are being accessed in the bilingual participants when performing the task in their L2.

Finally, and possibly the most striking finding of the study is the fact that in the comparison between radial categories and related controls, the monolingual group showed no differences in N400 amplitude, while the bilingual group showed increased N400 amplitude for radial categories than for related controls in left posterior and central brain sites.

The effect found in the monolingual group was unexpected, but a possible explanation can be that radial categories included radial categories with and without thematic links, with radial thematic categories -which accounted for half of the word pairs- being somewhat similar to related controls-. The heterogeneous nature of the radial categories, compared to classical categories and homonyms used in the present study could partly explain why the differences in N400 amplitude between related controls and radial categories failed to reach significance.

In the case of the bilingual group, the most plausible explanation for the differences found in N400 amplitude observed is that no access to L1 might have been involved when bilinguals performed the task with radial categories (or perhaps L1 access occurred in one type of radial categories but not in the other), and thus radial categories were treated as unrelated word pairs.

Summary

In the behavioural studies in this thesis, we proposed that the interaction between the lexico-semantic and conceptual systems is modulated by the type of category: The study in chapter five revealed conceptual transfer effects from the L1 to the L2 in classical, and to a lower extent, in radial categories. In the sixth chapter, performance in the lexical decision task was highest in the cases where conceptual and semantic category boundaries were congruent (i.e. in classical categories, where conceptual and semantic category boundaries are the same). In radial categories, performance in the task was slower than for classical categories (conceptual and semantic boundaries are not completely equivalent nor completely different).

The present study aimed to expand on the issue of the relationship between language and thought by examining whether access to the L1 semantic system in late L2 speakers of English occurs in all, or only certain category types. The results support the latter hypothesis: Access to L1 seems most plausible in classical and homonymic categories. In the case of classical categories, we can hypothesise that access to both conceptual and semantic stores is involved (most likely access to representations of the superordinate category level). On the other hand, access to the representation of a superordinate category is not possible in homonyms, given that the meanings of the prime and target are unrelated, so the observed relatedness (reduced N400 amplitude compared to unrelated stimuli) might reflect access to the L1 semantic system only.

In the case of radial categories, the larger N400 amplitude observed, compared to related control is in line with the findings of the previous chapter on semantic priming (namely slower RT relative to other category types), can be taken as an indicator of increased cognitive processing in accessing conceptual and semantic representation. The following chapter utilises fMRI to address the issue of amount and localization of cognitive processing in all three category types.

Chapter 8

fMRI Study Of Linguistic Transfer In Lexicalised Categories

8.1 Introduction

Differences in behavioural measures and the ERP time course of processing of classical, homonymic and radial categories have been shown in the previous studies. The present study used fMRI in order to build upon the findings of the previous studies and examine the neural correlates of representation and retrieval of s_wide (classical, homonymic and radial) categories, as well as potential differences in the processing of lexico-semantic knowledge between English monolinguals and late Spanish-English bilinguals. As noted earlier, in much of the neuroimaging literature, the term *semantics* is used to mean the representation of conceptual knowledge. However, the present chapter draws on previous research on conceptual knowledge and word meaning, and therefore, consistent with the convention used throughout this thesis, we will use the term “conceptual knowledge” instead of “semantic knowledge”. The term *semantics* will be reserved to refer to lexical semantics (word meaning).

The study of conceptual categories in the brain has traditionally been linked to lesion analysis and clinical neuropsychology studies, which have documented category-selective impairments (natural and man-made objects, faces, body parts, tools, animals and so forth) associated with different localised brain areas (Caramazza et al., 1990; Martin et al., 1996, Martin, 2007). More recently, the study of semantic dementia has given rise to models that aim to establish the neural site of amodal semantic representations. Given that damage in SD patients is located primarily in the anterior temporal lobes, these areas have been hypothesized to host the "semantic hub" which contains amodal representations (Patterson et al., 2007; Binder & Desai, 2009; Mion et al., 2010). The idea of a semantic hub is in contrast with the notion that knowledge is grounded in the sensory (modality specific) systems in the brain, as suggested by the "distributed views" (Patterson et al., 2007; Barsalou et al, 2008). In light of these conflicting views, some authors have attempted to integrate modality-specific and amodal representations, such as the "spoke-plus-hub" or "distributed-plus-hub" model (Patterson et al., 2007; Pobric et al., 2010; Pülvermuller et al., 2010), where modality-specific representations converge in a 'hub' that contains abstract representations. The hub integrates modality specific information and is recruited when interaction of the different modal systems or when interaction between the modal and amodal stores is needed (Mion, Patterson et al., 2010).

Common areas that are reported to be associated with access to the conceptual knowledge system are the fusiform and parahippocampal gyri in the ventral portion of the temporal cortex (Martin et al., 1996; Haxby et al., 2001; Chao et al., 2002); the dorsomedial prefrontal cortex (Damasio, 1981) and inferior frontal gyrus (Bookheimer, 2002; Devlin et al., 2003; Nyberg et al., 2003); the middle temporal gyrus and inferior aspect of the temporal cortex (Warrington & Shallice, 1984; Lambon et al., 2007).

While neuroimaging research on conceptual representations is mainly concerned with categories that are perceptual or functional, some authors have studied word meaning. Using behavioural measures, Dijkstra et al. (1988, 2002) proposed that lexical access entails access to not only orthographic representations, but also semantic content. Additionally, it has long been suggested that processing of word meaning involves two mechanisms: first accessing the knowledge about the meaning of the word and second, retrieving said knowledge in a way that is relevant to the task (Whitney et al, 2010). Several studies have reported activation of the left inferior frontal gyrus associated with access to a word meaning when there are other possible meanings competing for activation (Thompson-Schill, 1997). However, more recent studies have suggested that activation in the inferior frontal gyrus occurs when the context aids resolution of competition between different meanings of a word but not only when there is competition (without resolution) of different word meanings (Grindrod et al., 2008). Moreover, activity in the posterior middle temporal gyrus (pMTG) has been associated with semantic control (retrieval of the competing meanings of a polysemous word but also in indirect priming) rather than representation per se in a semantic paradigm during ambiguous contexts (Whitney et al, 2010).

Taken together, these findings suggest that the left inferior frontal and posterior middle temporal gyri form a larger network involved in the control of semantic retrieval, while the inferior temporal gyrus has been assumed to have a representational role. Furthermore, involvement of the fusiform gyrus in semantic processing has been proposed in several studies: The left fusiform gyrus has consistently been identified in tasks that involve word reading (Vigneau et al., 2005; Vogel et al., 2011) and has been termed "the visual word form area".

The left fusiform and parahippocampal gyri correlates with the degree of semantic deficit in semantic dementia patients in picture naming and category fluency, while damage in the right fusiform is associated with deficit in non-verbal semantic (conceptual) tasks (Mion et al., 2010).

Most research on representation and control in word meaning has used monolingual populations. Evidence from studies with bilingual populations suggests that semantic representation and control in bilinguals is substantially different than in monolinguals: bilinguals are slower in naming tasks and present a higher frequency of the tip-of-the-tongue phenomenon (Gollan et al., 2002, 2005). Moreover, some studies have revealed cognitive costs when switching from one language to the other, modulated by the level of proficiency in each language, suggesting that access to L2 is initially a controlled process that becomes more automatized as proficiency increases (Abutalebi, 2008). Fluent bilingual speakers need to deal with two lexico-semantic systems, which often arrange the conceptual space in different and often conflicting ways (Wierzbicka, 1996, Pavlenko, 1999, Levinson, 1997, Levinson, 1999), a fact that has raised the question of whether two languages share the same lexical system or whether they reside in separate stores (Indefrey & Levelt, 2004). A series of findings suggest that the two lexical systems share the same store: first, research on bilinguals has established that conceptual access is non selective, more specifically, that access to concepts activates semantic representations in both languages (Dijkstra & Heuwen, 2002), and second, it has been shown that in bilinguals, the non-active language is still activated when performing a task in the active language. A series of experimental evidence support the notion of the non-selective access to the lexicon. De Bot (2004, p. 23-24) argued that "access to words in the lexicon is non-selective, i.e. words from more than one language compete for activation both in production and perception, but a –still to be defined- minimal level of proficiency/activation is needed to have words from a language play a role in the selection process, i.e. their default level of activation should be high enough to make them competitive"

The previous chapters have provided behavioural and imaging support for the notion that category boundaries are affected by cross-linguistic influence, more specifically, in category boundaries. In the present study, fMRI Blood Oxygen Level Dependent (BOLD) signal was used to identify the neural circuitry associated with semantic retrieval and representation of classical, homonymic and radial categories. We recruited a group of monolingual English speakers and a group of late Spanish-English bilinguals. For the bilingual group, the task was designed to induce interference from the L1 (Spanish) category system when performing a task in the L2 (English). A potential interference would happen automatically, as activation from the L1 category system would spread to the L2 category system. In order to detect any automatic effects, a short-SOA semantic priming paradigm with an implicit task was used. Semantic priming in conjunction with an implicit task has been widely used to explore automatic semantic processing (Kuperberg et al., 2008), and it is hypothesised to reflect the automatic spread of activation across memory (Collins & Loftus, 1975).

Furthermore, the use of a short SOA was justified in order to avoid controlled processes such as the generation of expectations on the next word, or postlexical efforts to integrate the prime and target words. fMRI was used in order to obtain information about the potential localisation and patterns of neural activity associated with category representation and retrieval of lexico-semantic knowledge in monolinguals and bilinguals.

8.2 fMRI BOLD Principles

The aim of functional magnetic resonance imaging is to display patterns of neural activation associated with different cognitive tasks. In order to achieve such aim, the fMRI technique measures changes in the level of oxygen that is present in the blood. The changes in the level of oxygen are associated with neural activity. This phenomenon is known as the BOLD (blood oxygen level dependent) effect. A very simplified account of the BOLD effect is as follows: when a particular region in the brain becomes engages in a task (thus becoming active), there is an increase in the metabolism of the neurons that are present in the area, which involves increased oxygen consumption. Consequently, the blood that is present in the area will contain a higher proportion of deoxihemoglobin (hemoglobin without oxygen) than oxihemoglobin (hemoglobin that carries oxygen). In order to aid the metabolism, the body responds by increasing the flow of oxygenated blood to the brain region that is active, and given that oxihemoglobin and deoxihemoglobin have different magnetic properties, an MRI scanner -which contains a powerful magnet within its bore- can differentiate the signal produced by the active brain region, where the concentration of oxyhemoglobin is higher from the non-active (or less active) brain areas.

Spatial Resolution

Even though fMRI provides higher spatial resolution than other techniques such as EEG) there are inherent limitations in terms of how accurate the localisation of the signal is. There are two main phenomena that decrease spatial accuracy. First is the fact that blood flow is increased for a larger area than the active one, which results in activation in the fMRI signal in an area that is larger than the active one, and second is that additionally, BOLD signal is obtained in large veins that are a couple of millimetres away from the neutrally active area (Ugurbil, Toth & Kim, 2003).

Temporal Resolution

Due to the nature of the BOLD signal, fMRI does not provide as high temporal resolution as other techniques. Blood flow is not immediate: it takes time for the blood to reach the brain areas that are active, and this is reflected in the BOLD signal, which takes two to three seconds to rise above baseline, and four to six seconds to peak. Consequently, the measured signal is much slower than the actual neural activity.

Predictions

In line with previous research (Sebastian et al., 2011), it was expected that the bilingual group would show higher and more spread neural activity, reflecting increased cognitive load due to performing a task in the non-native language, compared to the monolingual group. An increased cognitive load could be expected in frontal regions, especially in left inferior frontal gyrus, posterior middle temporal gyrus (Sebastian et. al, 2011, Grindrod et al., 2008). Increased cognitive demands would most likely to occur in homonyms, consistent with the notion that different meanings in homonymic categories correspond to different, separate lexical entries, and also because these different meanings are not conceptually related. Additionally, given that s_wide stimuli are only lexicalised with a single word in Spanish, it is not yet clear whether there will be a facilitation or an inhibition effect in processing s_wide categories compared to related controls would take place when performing the task in English. Furthermore, additional involvement of the temporal, fusiform and parahippocampal areas could be possible in s_wide stimuli, (especially in radial and classical categories) relative to unrelated controls, if areas involved in the representation of conceptual relations between prime and target words were recruited.

8.2 Method

Stimuli

The stimuli used in this study were s_wide, related control, unrelated control categories and non-word pairs, as described in chapter 4. As with the previous behavioral & ERP studies, s_wide stimuli and related controls were divided into classical categories, homonyms and radial categories.

Participants

Nine native monolingual English speakers (8 males, 1 female) and eight native Spanish speakers (5 females, 3 males) who were highly fluent speakers of English as a second language participated in this study. All participants reported being right handed, having normal or corrected to normal vision and were recruited in North Wales, UK. Data from one participant in the bilingual group was excluded, since it showed a large percentage of errors.

The English monolingual group consisted of native monolingual English speakers who did not speak or understand other languages. Mean age for the English monolingual group was 24 years (range 19-33 years, SD=5). The Spanish-English bilingual group consisted of participants born in Latin America who were working or studying in North Wales. Mean age for the Spanish group was 33 years (range 27-42 years, SD=5). While the difference in age between language groups was significant (t_{16} =-3.463; p=0.003), and could potentially affect overall reaction times, examining reaction time differences between the two language groups was not one of the objectives of the present study. Slower reaction times for bilinguals, compared to monolinguals in linguistic tasks conducted in the participants L1 are well documented in previous studies (Gollan et al., 2002, 2005), and therefore reaction time differences where already expected for bilinguals throughout the task. Additionally slower reaction times for the bilingual group were expected, since participants were performing the task in their L2 (non native language). However, it was important to ensure bilingual participants had an extensive English vocabulary, in order to complete the lexical decision task.

In order to confirm a high level of proficiency in English, participants a language background questionnaire was administered (see appendix 5).

(1) Bilingual participants reported having initiated the learning of English after 10 years of age (Mean = 12.21, SD=6.79).

(2) Furthermore, participants in the bilingual group also reported their competence in reading and understanding English as high or very high in a five point Lickert scale (Mean = 4.44, SD = 0.527, where 1 corresponded to very low competence, 3 was intermediate competence and 5 was very high competence).

(4) In addition, to ensure that the knowledge of the English vocabulary was reasonably comparable between Spanish-speaking and English-speaking participants, the BPVS test British Picture Vocabulary Scale (BPVS; Dunn, Dunn, Whetton & Burley, 1997) was administered to all participants. The monolingual English group obtained a standardised score of 120.40 (SD=8.140), while bilingual Spanish speakers obtained a score of 117.38 (SD=6.391). A means comparison of the BPVS scores revealed no significant difference between language groups ($t_{16} = 3.672$; $p>0.05$).

Procedure

The presentation of the stimuli was controlled with a script written in E-Prime v.2.0 (E-prime Psychology Software Tools Inc., Pittsburgh, USA) running on a Mac Pro computer. The stimuli that participants viewed were string characters (words and non-words) projected onto a screen, viewed through a mirror attached to the head coil.

An event-related design was used to present trials in four runs, with each run containing 48 S_wide items, 48 related controls, 48 unrelated controls and 144 non-words. Stimuli were divided into four runs. Each run contained the same stimuli for each participant, however the order of presentation was randomised within each run for every participant. The stimuli used can be found in appendix 4. Each trial started with the presentation of a mask character string ("******") for a randomly jittered period of time that ranged from 1000 to 8000 ms., followed by the brief presentation of the prime word for 70 ms. Then, the mask character string was presented again for 500 ms., immediately followed by the target (second word in an item) for 1000 ms**.** During presentation of the target stimulus, participants were required to make a response by pressing buttons using a response keypad placed in their right hand using their right thumb. Throughout the task, participants were asked to, as fast as possible, press the uppermost button if the character string presented on screen was a real English word. If the character string presented was not a real English word, participants had to press the second uppermost button. When a response was made or after 1000 ms. of the presentation of the target item (whichever came first), the trial was completed and a new trial started.

fMRI Data Acquisition and Pre-Processing

Data were acquired using a Phillips Achieva 3T MRI scanner (Philips medical systems, Best, The Netherlands), using standard gradients and a circular polarized phase array head coil. Subjects lay in a flat bed, and head movement was limited using foam padding in the head coil. Noise was minimised by means of ear-plugs and headphones. For each functional run a series of 214 functional volumes of T2-weighted axial EPI scans (28, RT) were acquired, lasting 7 minutes each. The scanning was paused between runs, to ensure participants were ready to continue. Scans covered the whole brain parallel to the AC/PC line with the following parameters: number of slices (NS), 28; slice thickness (ST), 3 mm; matrix size (MS), 96x96 voxels; field of view (FOV), 240 mm; echo time (TE), 30 ms.; repetition time (TR), 2000 ms. Five initial dummy scans were inserted at the beginning of the sequence to enhance image stability. For anatomical localisation, high-resolution T1 images were acquired.

Pre-processing

Analysis of the fMRI data was performed using the Brain Voyager QX 2.3 software package for Macintosh (Brain Innovation BV, Maastricht, The Netherlands). Functional data from each participant were pre-processed using slice-scan timing correction, spatial realignment, normalisation, co-registration and smoothing.

Slice-time correction was performed to minimize inter-slice temporal differences When the distance between the reference and the brain location of interest increases, so does the possibility is that any observed effects in those areas are, in fact, errors of interpolation (Veltman & Hutton, 2001). Consequently, the middle slice was used as the reference point, and data from other slices were interpolated towards the reference slice.

In the spatial realignment stage, volumes were corrected for participant head movements. The corrections were performed with a six-parameter rigid body transformation (shifts in the x, y, z axes and rotations in the x, y, z axes). Following this stage, spatial normalisation was performed, in order to correct for differences in the volumes obtained from the participants (who have different sizes, shapes and brain orientation). Functional brain volumes were co-registered with the high-resolution anatomic volumes, and transformed to the standard Talairach space (Talairach and Tornoux, 1988). In order to increase the signal-to-noise ratio in the fMRI signal and also to correct for residual anatomical differences across participants, the normalised volumes were then spatially smoothed using an 8 mm full-width half-maximum Gaussian kernel. In addition, signal drift due to scanner heat up was corrected with linear de-trending and a high pass filter of 3 cycles/run.

8.2 Behavioural Results

Accuracy: Percentage of errors

To explore whether the percentage of errors produced by each language group differed, and to exclude potential participants who had made a high number of errors and could thus bias the imaging data, the percentage of errors made by each participant was computed. Given that stimuli presentation was automatic, there was the possibility that participants left trials without a response, so percentage of errors was taken as the most accurate measure of error production.

Errors in the task were coded as false positives (trials where participants indicated that they saw a "real" word when a non-word was presented on screen), or misses (trials where participants indicated non-word when a "real" word was presented on screen).

Overall percentage of errors (giving the wrong response) in the task was 7.89% for bilingual group and 5.88% for the monolingual group. Overall percentage of omissions (trials left without response) was and 18.90% for bilinguals and 13.68% for monolinguals. The highest number of omissions took place in the non-word condition, for both the bilinguals (33.85%) and monolinguals (22.74%).

As mentioned earlier, one participant in the bilingual group was excluded, as he/she presented a high percentage of errors (41.77% errors). After participant exclusion, the effective sample size was N=16 (seven bilingual and nine monolingual participants). Table 8.1 shows the percentage of errors divided by category type, condition and language group.

MONOLINGUALS	OMISSIONS	ERRORS	CORRECT
S_WIDE CLASSICAL	14.06 %	2.34 %	83.59 %
RELATED CONTROL CLASSICAL	10.94 %	12.50 %	76.56 %
S_WIDE HOMONYMS	10.16 %	7.03 %	82.81 %
RELATED CONTROL HOMONYMS	16.41 %	4.69 %	78.91 %
S_WIDE RADIAL	15.63 %	4.8 %	79.69 %
RELATED CONTROL RADIAL	8.59 %	8.59 %	82.81 %
NON-WORD	22.74 %	4.51 %	72.74 %
UNRELATED CONTROLS	10.94 %	2.60 %	86.46 %
BILINGUALS	**OMISSIONS**	**ERRORS**	**CORRECT**
S_WIDE CLASSICAL	17.19 %	2.34 %	80.47 %
RELATED CONTROL CLASSICAL	24.22 %	12.50 %	63.28 %
S_WIDE HOMONYMS	15.63 %	4.69 %	79.69 %
RELATED CONTROL HOMONYMS	10.94 %	7.23 %	82.03 %
S_WIDE RADIAL	17.97 %	7.01 %	75.00 %
RELATED CONTROL RADIAL	12.50 %	2.34 %	85.16 %
NON-WORD	33.85 %	19.10 %	47.05 %
UNRELATED CONTROLS	11.20 %	2.08 %	86.72 %

*Table 8.1:*Percentage of errors according to category type and language group.

Reaction Times

Reaction times across category types were compared using a repeated measures ANOVA, again with category type (classical, homonym, radial) and condition (s_wide, related control) as within-subject factors and language group (bilingual, monolingual) as between subject factors. The analysis revealed no effects of category type, condition or language group, but there was a significant interaction effect of Category Type X Control, $F(2,30) = 15.534$, $p<0.001$) . In this case, reaction time for classical categories was significantly faster in the s_wide than in the related control condition $t_{16} = 2.997$, $p = 0.009$, (RT s_wide = 694.35 ms., RT related controls = 734.24 ms.).

8.3. Imaging Results

Statistical Analysis

After all volumes were pre-processed, they were analysed in two stages. In the first stage, data were analysed using a random (RFX) effects GLM. As is common practice in fMRI studies, a RFX GLM was chosen over a fixed effects (FFX) GLM because it enables the generalisation of the results to a population level: While FFX concatenates data from all participants and treats it as a single subject (the error variance is estimated by the variability across individual time points), in the RFX analysis, the error variance is estimated by the variability of subject-specific effects across subjects.

As a result of the first step, a separate set of beta values for each subject in each condition were obtained. Beta values are used to define the contribution of each experimental condition to the observed data.

In the second stage, we performed a multi-factorial ANOVA design with one between-subjects factor, language group (monolingual or bilingual), and two within-subjects factors, category type (classical, homonyms, or radial) and control (s_wide or related controls), both unrelated controls and non-words were excluded from the analysis, since these were not needed to answer the research questions of the study, and given the relatively low number of participants per language group (eight bilinguals and nine monolinguals), a simpler design would allow for a higher statistical power.

In order to calculate beta weights per subject per predictor was computed. Once a statistical map was obtained, a threshold of 0.02 was set and we performed a correction using the cluster-level statistical threshold estimator plugin for BrainVoyager (Goebel, Esposito & Formisano, 2006), with a Full width at half maximum (FWHM) of 1.380 voxels, without applying a mask to the random 3d images, and using 1000 iterations for the simulation. Cluster thresholding has been assumed to be more sensitive to effects in the signal than simple-voxel based thresholding (Friston et al., 1996).

After the corrected statistical volume map was obtained, effects of interest (beta weights) were extracted from the resulting clusters to demonstrate the degree of brain activations of different conditions, and a table with beta plots was obtained in order to examine the pattern of activations of the two participant groups across conditions.

Imaging data results

The RFX analysis revealed main effects of category type, language group and condition. These are summarized below. Voxel sizes and Talairach coordinates are shown in table 8.2.

Language group

The comparison of language groups revealed increased activation in four clusters for bilinguals, compared to monolinguals. The first cluster (6514 voxels) comprised areas in the right inferior and middle occipital gyrus (Brodmann areas 18 and 19). The second cluster (663 voxels) comprised parts of the right angular gyrus, right middle temporal gyrus and right precuneus (Brodmann 39). The third cluster (548 voxels) comprised areas in the left fusiform gyrus (Brodmann area 18 extending to area 19) and left inferior occipital gyrus.

Finally, the fourth cluster (440 voxels) comprised areas of the left occipital gyrus. Clusters that showed higher activity for bilinguals than monolinguals in the overall task are shown in figures 8.1 through 8.6.

Type

Comparison of classical, homonyms and radial category type revealed increased activation for homonymic compared to radial categories in a cluster (396 voxels) that covered parts of the left parahippocampal gyrus, left hippocampus, and left caudate tail.

Condition

Increased activation for related controls than for s_wide stimuli was revealed in one cluster (2670 voxels) which comprised areas of the right putamen, right globus pallidus and right lentiform nucleus.

Region	Size (Voxels)	Talairach Coordinates (peak voxels) X	Y	Z	F
Bilinguals > Monolinguals					
Right inferior occipital gyrus Middle occipital gyrus	6514	37	-87	0	7.824
Right angular gyrus, Right middle temporal gyrus Right precuneus	663	46	-71	33	4.782
Left fusiform gyrus Left inferior occipital gyrus	548	-26	-89	-15	6.86
Left inferior occipital gyrus	440	-38	-86	-3	14.15
Homonyms > Radial					
Left parahippocampal gyrus Left hippocampus Left temp lobe (caudate) Left caudate tail	396	-32	-32	-3	7.9621
Unrelated controls > S_wide					
Right putamen Right globus pallidus Right lentiform nucleus	2670	21	2	12	10.33

Table 8.2: Clusters of activation for the overall task, by category type, language group and condition

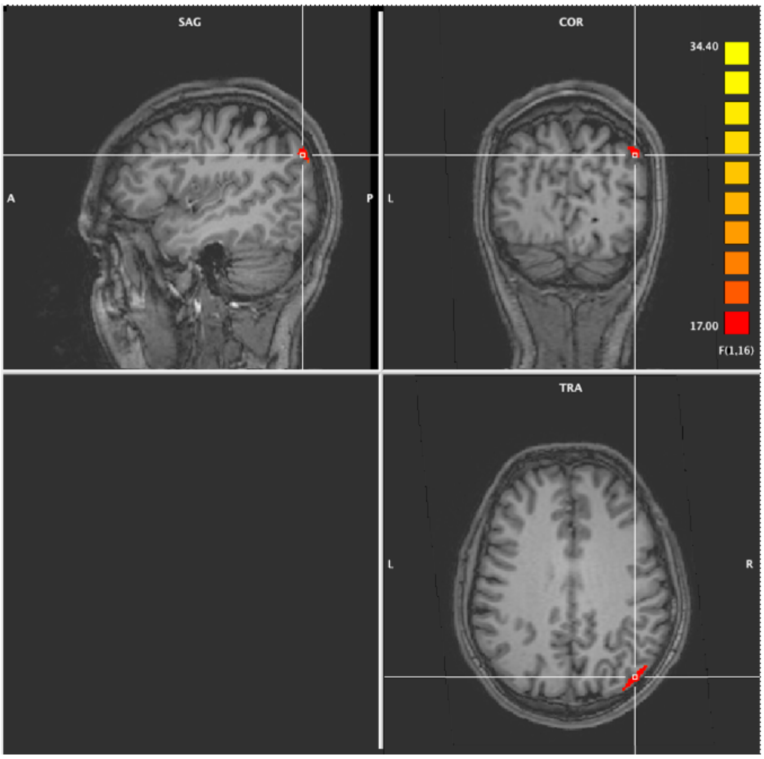


Figure 8.1: Increased activity in a cluster in the right inferior occipital gyrus and middle occipital gyrus in bilinguals, compared to monolinguals.

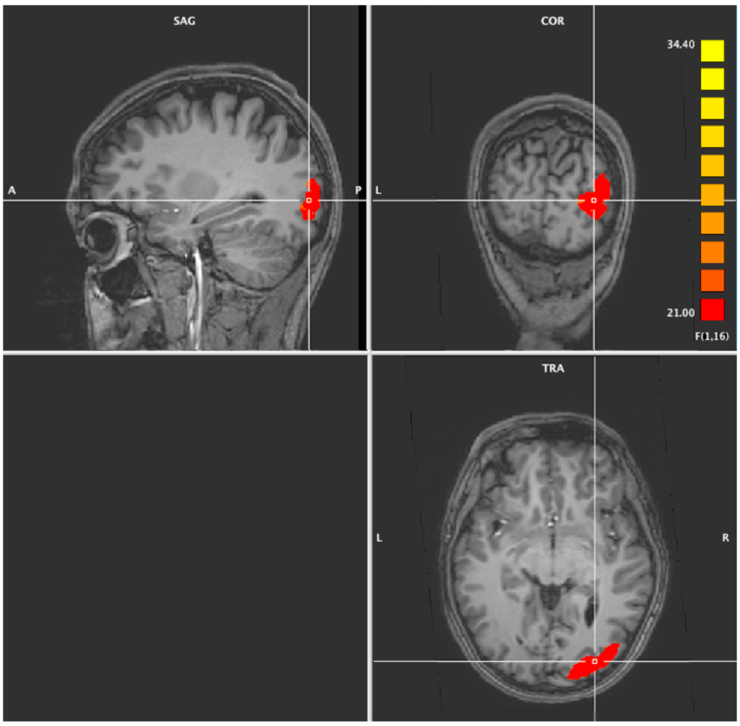
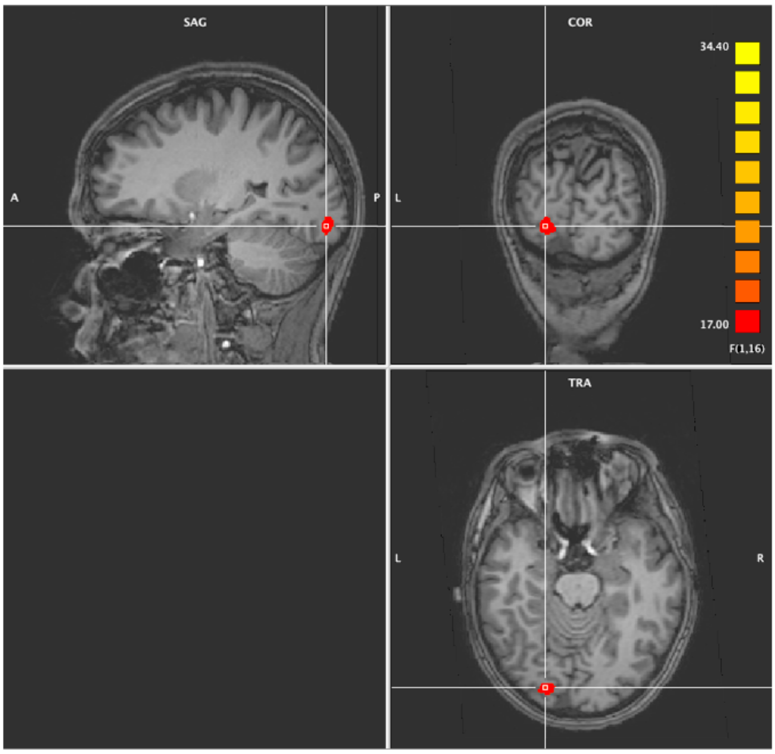


Figure 8.2: Increased activity in a cluster in the Right angular gyrus, right middle temporal gyrus and right precuneus in bilinguals, compared to monolinguals.



s

Figure 8.3: Increased activity in a cluster in the left fusiform gyrus and left inferior occipital gyrus in bilinguals, compared to monolinguals.

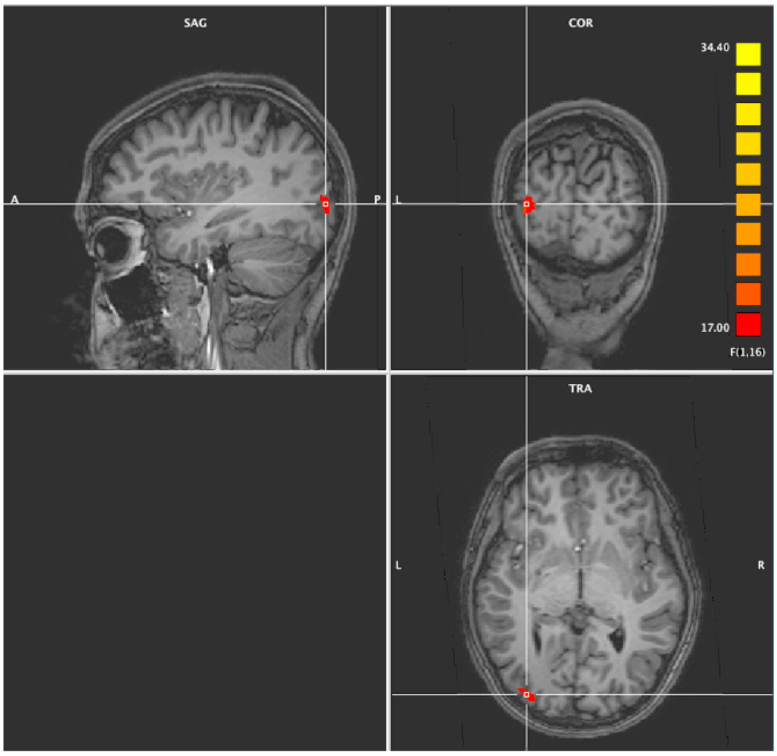


Figure 8.4: Increased activity in a cluster in the left inferior occipital gyrus in bilinguals, compared to monolinguals.

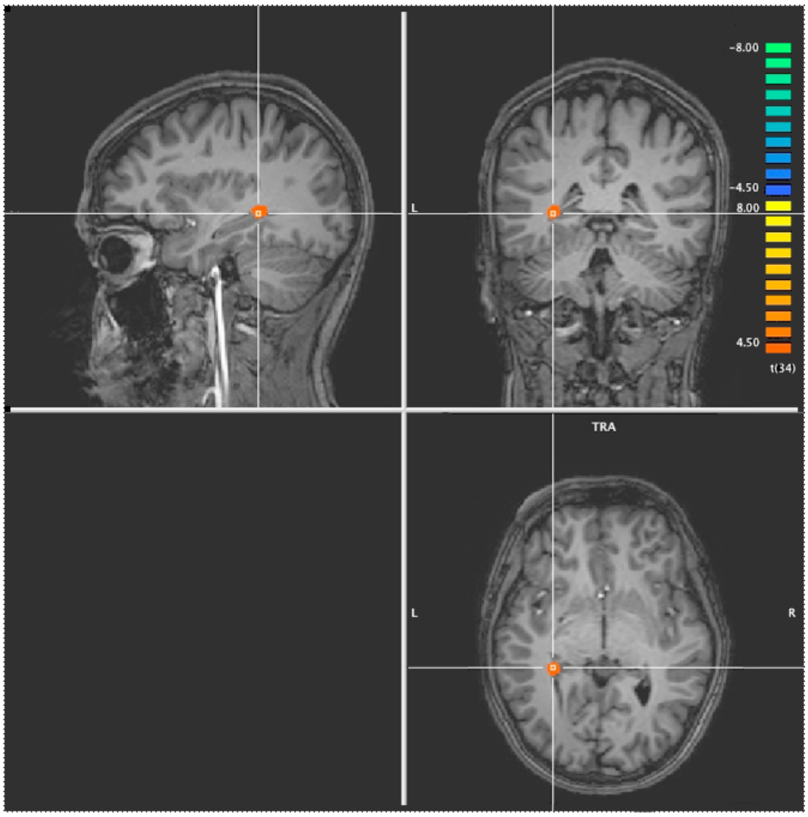


Figure 8.5: Cluster in the left parahippocampal gyrus, extending to left hippocampus, left temp lobe (caudate) and left caudate tail. The cluster showed higher activity in bilinguals, compared to monolinguals.

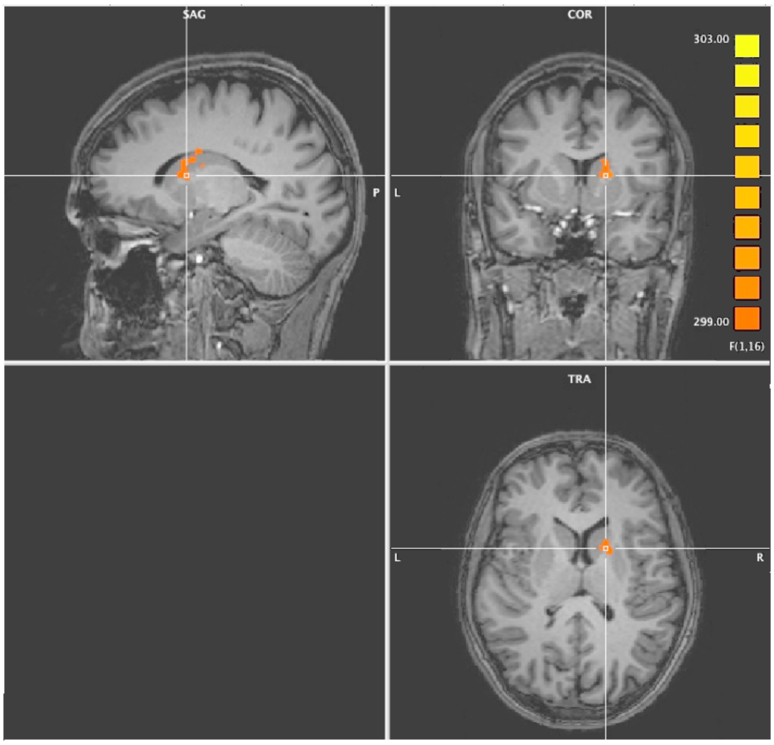


Figure 8.6: Increased activity in a cluster in the right putamen, right globus pallidus and right lentiform nucleus in bilinguals, compared to monolinguals.

The analysis of interaction effects revealed interactions of Category Type X Language Group, Language Group X Condition and Category Type X Condition. These effects are summarized below. Voxel sizes and Talairach coordinates are shown in table 8.3

Category Type by Language Group interaction effects

In the monolingual group, no differences in activation were found between classical and homonyms, between classical and radial or between homonym and radial category types. However, in the bilingual group, activity was shown in three different clusters, differently for each category type. *Homonym > Radial* : Significantly higher activation for homonym than radial categories was revealed in a cluster (6514 voxels) that covered areas of the right and left middle and inferior occipital gyrus (Brodmann areas 18 and 19), see figure 8.7.

Classical > Radial: Significantly higher activation for classical than radial categories was shown in a cluster (440 voxels) that covered areas of the left middle and inferior occipital gyrus, see figure 8.8.

Radial > Classical: Significantly higher activation for radial than classical categories was shown in a cluster (393 voxels) that covered areas in the right middle temporal gyrus, see figure 8.9.

Language Group by Condition interaction effects

Interaction effects of Language Group X Condition revealed no differences in brain activation between s_wide and related controls in bilinguals, and no differences between s_wide and related controls in monolinguals. Additionally, no differences in brain activation between monolinguals and bilinguals in the s_wide stimuli were found. However, there were differences between bilinguals and monolinguals in the processing of related controls. The analysis revealed activity in three clusters where activation was significantly higher for bilinguals than monolinguals (see figures 8.10 to 8.13).

The first cluster (1231 voxels) comprised areas of the left middle and inferior occipital gyrus (Brodmann area 19), left lingual gyrus and left fusiform gyrus.

The second cluster (692 voxels), which also showed activity in the Category Type X Language Group section) comprised areas of the right inferior frontal gyrus (Brodmann areas 9 and 49), and the right middle frontal gyrus.

Finally, the third cluster (402 voxels) covered areas of the left supramarginal gyrus (Brodmann area 40) and left superior temporal gyrus (Brodmann area 39).

Category Type by Condition interaction effects

No differences in activation were found in related control stimuli across category types. However, in s_wide categories, a cluster comprising areas in the left parahippocampal gyrus (Brodmann areas 27,28, 35 and 36) and in the left hippocampus showed larger activation in classical than radial categories and larger activation in homonyms than in radial categories.

Region	Size (Voxels)	Talairach Coordinates (peak voxels)			F
		X	Y	Z	
CATEGORY TYPE x LANGUAGE GROUP (Bilinguals only)					
<u>Homonym > Radial</u> right middle occipital gyrus right inferior occipital gyrus	6514	37	-87	0	18.056
<u>Classical > Radial</u> Left middle occipital gyrus Left Inferior occipital gyrus	440	-38	-86	-3	14.854
<u>Radial > Classical</u> RIght Middle temporal gyrus	393	47	-41	0	10.834
LANGUAGE GROUP x CONDITION () (All Bilingual > Monolingual)					
Left middle occipital gyrus Left Inferior occipital gyrus Left lingual gyrus Left fusiform gyrus	1231	-12	-34	19	10.935
Right inferior frontal gyrus Right middle frontal gyrus	692	53	13	28	10.935
Left middle occipital gyrus Left supramarginal gyrus Left superior temporal gyrus	402	-59	-53	27	4.061
CATEGORY TYPE x CONDITION (All participants)					
Left parahippocampal gyrus, Left hippocampus	781	-26	-26	-6	6.984

Table 8.3 : Clusters of activation in interaction effects

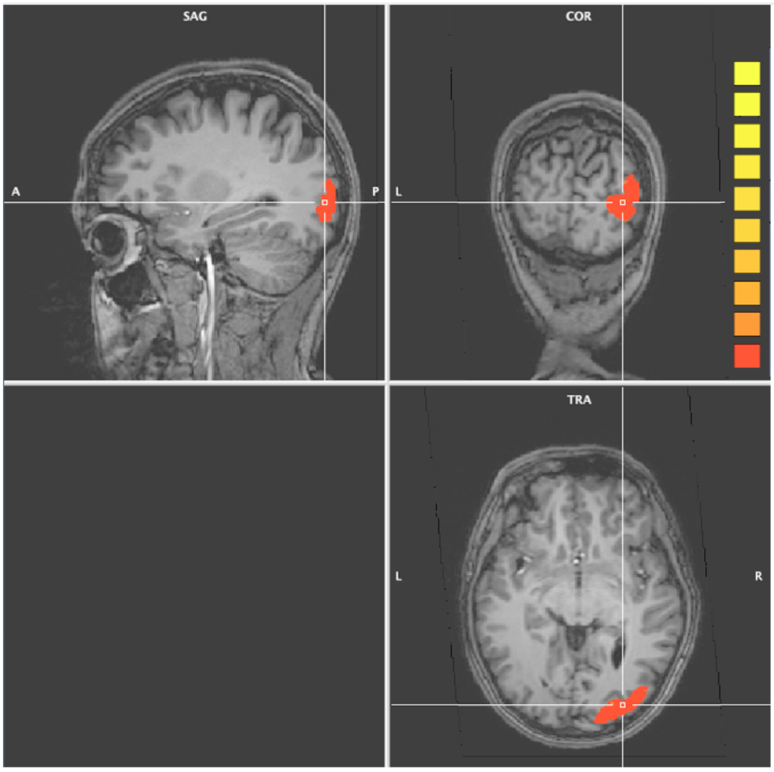


Figure 8.7: Bilinguals showed increased activity in a cluster in the right inferior and middle occipital gyri when processing homonymic, compared to radial categories.

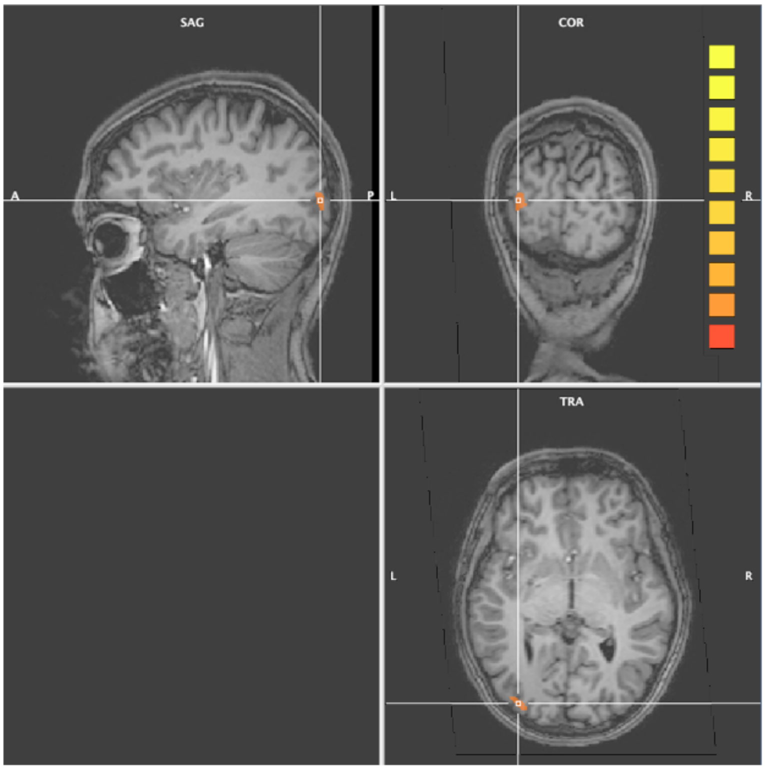


Figure 8.8: Bilinguals showed increased activity in a cluster in the left inferior and middle occipital gyri when processing classical, compared to radial categories.

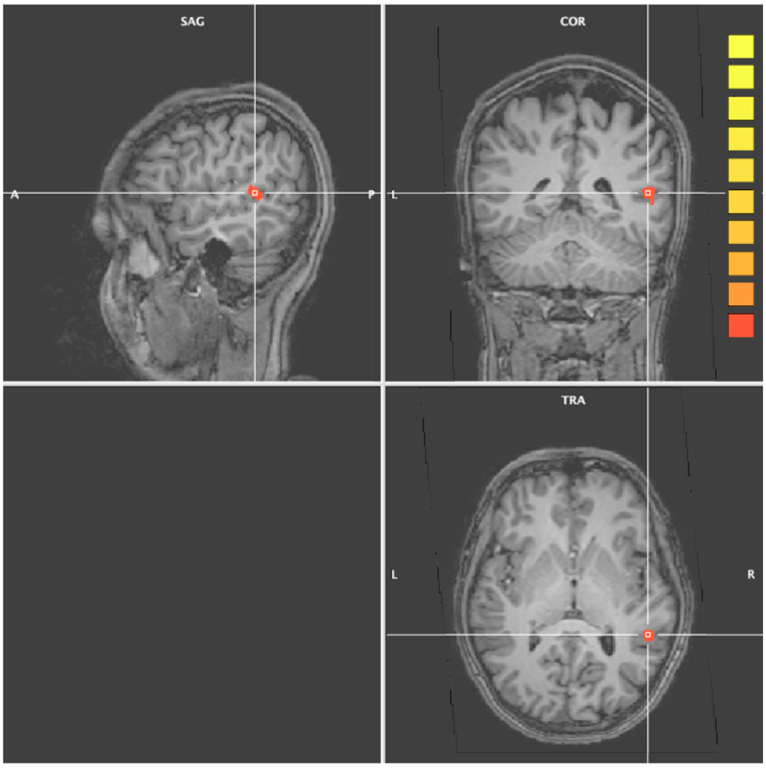


Figure 8.9: Bilinguals showed increased activity in a cluster in the right middle temporal gyrus when processing radial, compared to classical categories.

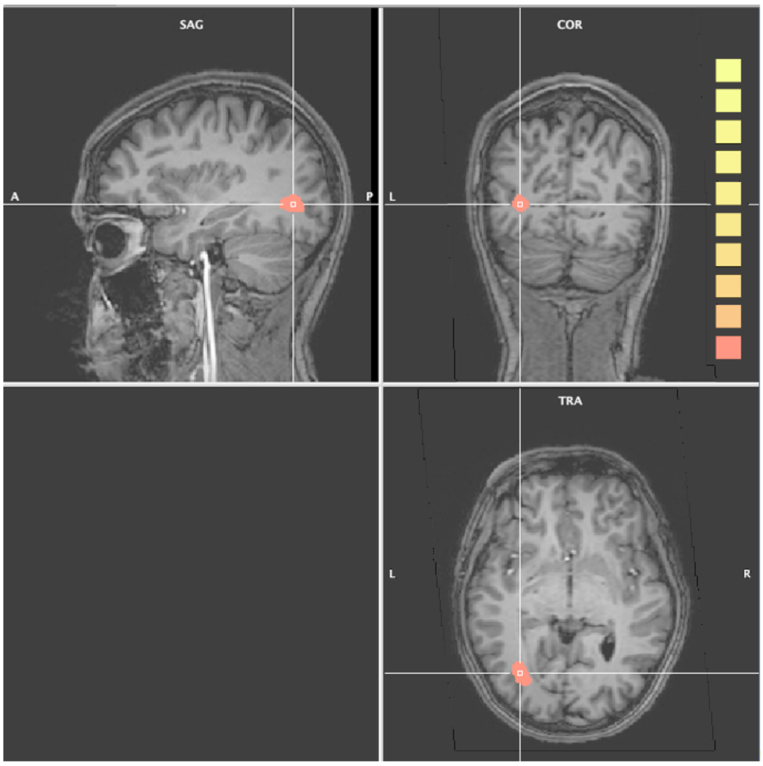


Figure 8.10: Bilinguals showed increased activity, compared to monolinguals, in a cluster in the left middle and inferior occipital gyri, and left lingual and fusiform gyri when processing related control stimuli.

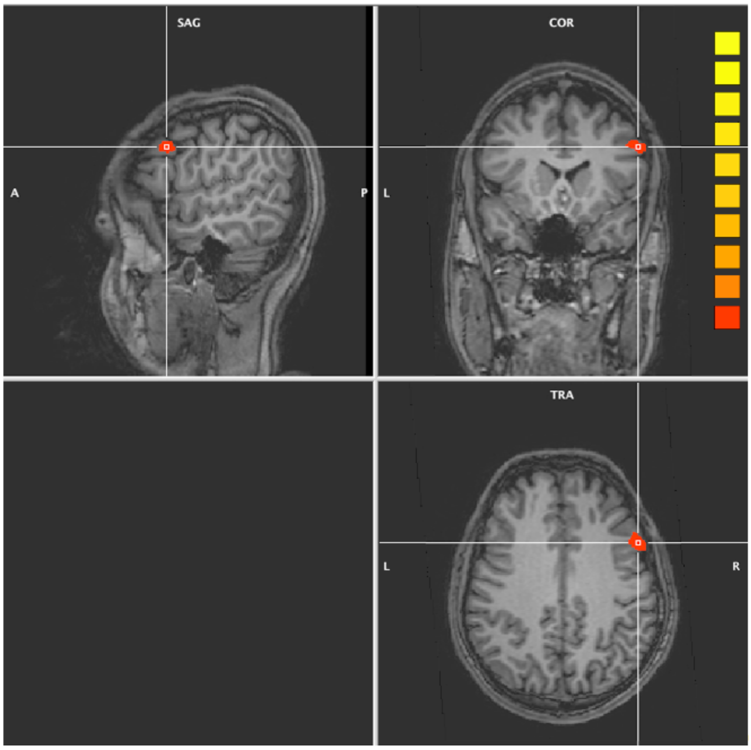


Figure 8.11: Bilinguals showed increased activity, compared to monolinguals, in a cluster in the right inferior and middle frontal gyrus when processing related control stimuli

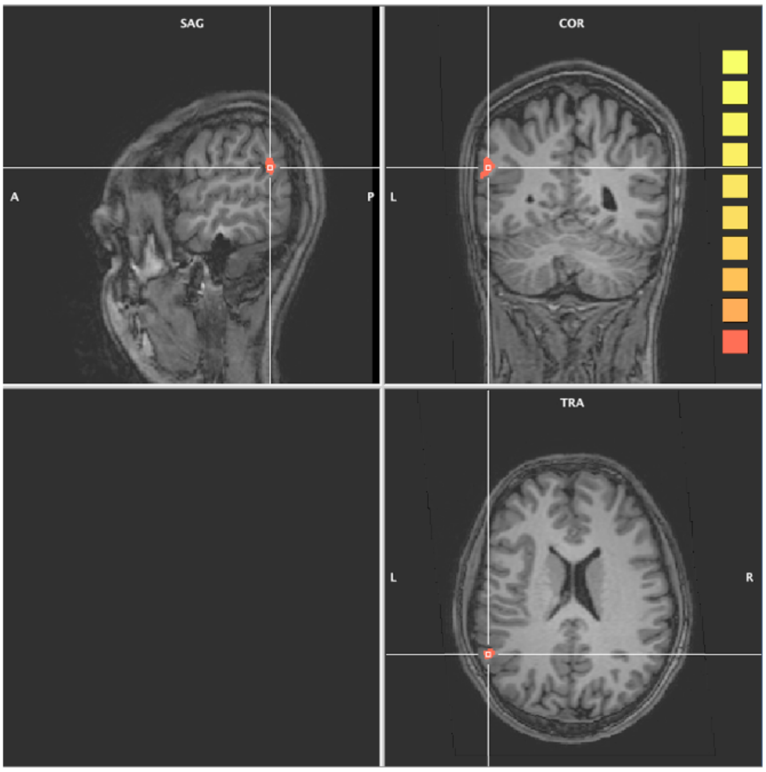


Figure 8.12: Bilinguals showed increased activity, compared to monolinguals, in a cluster in the left supramarginal and left superior temporal gyri when processing related control stimuli

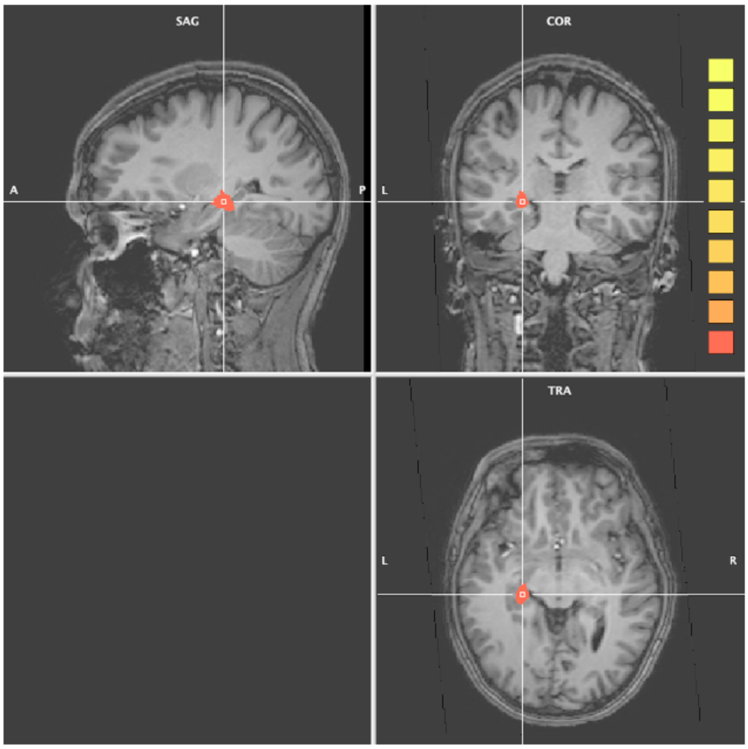


Figure 8.13: Bilinguals showed increased activity in a cluster in the left parahippocampal gyrus and left hippocampus when processing classical and homonymic, compared to radial categories

8.4 Discussion

The experimental literature on the bilingual lexicon provides abundant evidence for the need for bilingual speakers to access often conflicting semantic systems and category structures**.** Furthermore, neuroimaging studies suggest that lexical access in the bilingual lexicon is non-specific and that in bilinguals, the non-active language is partially activated in monolingual tasks (De Bot, 2004. Van Hell & Dijkstra, 2002).

The present study compared late bilingual, highly proficient Spanish-English bilinguals and English monolinguals in an implicit masked priming paradigm, using a lexical decision task. It was hypothesised that, since the bilingual sample consisted of late bilinguals who were non native in English, access to L2 (English) categories would be mediated by their L1 (Spanish). For instance, processing the English (L2) target word *wrist* would involve accessing its Spanish (L1) translation *muñeca.* However, in Spanish, the word form *muñeca* denotes both DOLL and WRIST, so hypothetically, if the Spanish word form becomes active, processing of *doll* -> *wrist* could be faster than *doll* -> *pen* (*muñeca – bolígrafo,* two words that are not semantically encoded in a s_wide category in Spanish).

The main objective of the present study was to explore the patterns of activation associated with the processing of different S_wide category types (Classical, Homonyms, Radial). The category types used are assumed to involve different degrees of reliance upon the conceptual system and upon language conventionalisation, where classical categories are the most 'conceptual' and least reliant on language conventionalisation, homonyms are the least ‘conceptual’ and most reliant on language conventionalisation and radial categories are in between classical and homonymic categories.

A secondary objective of this research was to examine differences in patterns of neural activation of L1 and L2 lexical and semantic retrieval processes, by comparing the monolingual group, who were performing the task in their first language, and the bilingual Spanish group who were performing the task in their second language.

Behavioural Results

Given that S_wide categories were designed to be meaningful to to Spanish speakers only, priming from the prime word to the target would be expected in the bilingual but not in the monolingual group. However, it has been documented that access to L2 is slower than L1 (Gollan et al, 2005) with words in the L2 lexicon having a lower functional frequency (Abutalebi & Green, 2007), and consequently, faster reaction times due to facilitation effects could possibly be cancelled by the fact that the bilinguals were operating in their L2. Consistent with this notion, no differences in reaction times between bilinguals and monolinguals were found, although classical categories were processed faster in the S_wide than in the related control condition for all groups**.** The RT difference observed could reflect an effect of relatedness, because in classical s_wide there is a stronger conceptual relation between the two words of the categories, regardless of language group.

Imaging Results

Comparison of category types: all participants

Differences in patterns of neural activation were expected in all participants, since s_wide classical categories are related conceptually, regardless of the language of the participants, while homonyms are not related conceptually but are conventionalised in the Spanish language.

The imaging data analysis revealed that for all participants, homonymic categories were associated with higher neural activation than radial categories in left parahippocampal gyrus, left hippocampus and the tail of the caudate nucleus in the left temporal lobe. The left hippocampal gyrus has been assumed to be part of the so called "semantic network", which is lateralised to the left hemisphere and which is hypothesised to be responsible for the representation of conceptual knowledge (Binder et al., 2009). Likewise, the hippocampus has traditionally been assumed to have a role in the representation of declarative memory and conceptual knowledge, and damage to the hippocampus is also present in semantic dementia patients (Patterson, 2008). On the other hand, damage to the tail of the left caudate nucleus has been associated with impairment in naming tasks and difficulties finding words (Cappa et al., 1992), and in involuntary language switching in bilinguals (Abutalebi et al., 2000). Activity in the caudate has been reported in a semantic decision task where prime and target words were conceptually unrelated or in different languages (i.e. *Salmon – Lachs* where *lachs* is the German word for salmon), compared to the condition where prime and target words were related (Crinion et al,. 2006). There are several plausible explanations for the activity shown in the left parahippocampal gyrus, left hippocampus and tail of the left caudate nucleus shown in all participants during the processing of homonyms but not radial categories. First, it could be that increased activation indicates that homonyms are processed with greater effort than radial categories, consistent with the fact that words in the homonymic condition were not related conceptually. Alternatively, it could be that the observed difference in activation reflects a reduced cognitive load in processing categories where there is a conceptual relationship between words, but not in word pairs that are not related conceptually, such as homonyms.

Comparison of category types: Bilingual participants only

In the bilingual group, both classical and homonyms were associated with higher neural activity than radial categories in the occipital regions: right middle and inferior occipital lobe in the case of homonyms, and left inferior and middle occipital lobe in the case of classical categories.

The effect of lateralisation of activity in classical and homonyms might potentially reflect the level of effort required in order to process the relationship between words in each category. Activity in the occipital regions has been reported in studies that used written words. Specifically, inferior occipital regions have been assumed to have a role in orthographic processing (Richardson et al., 2011), and that reading expertise is associated with a reduced need for right hemisphere visual processing. In the present study, processing of classical categories could reflect retrieval of features that are relevant to both meanings of the word, such as knowing that an object is a body part, articulated, found at the end of the limbs, such as in FINGER-TOE. Consistent with these findings, some studies have shown dissociation in left versus right occipital regions in category representation. Processing of stimuli relating to animals was associated with activity in left inferior occipital regions compared to tools (Caramazza & Mahon, 2006), a pattern of activation that suggests that retrieval of meaning in categories that fit the classical theory on categorisation (i.e. categories defined by a set of features) is associated with activity in the right occipital region.

On the other hand, retrieving word meaning for homonyms would entail access to two separate entries in the lexicon (such as SAIL and CANDLE). Access to more than one entry in the lexicon could arguably be a more effortful task than retrieving a single meaning, and would involve an increased need for right hemisphere visual processing (in the right occipital region).

Regarding radial categories, the difference in level of activation between radial and classical categories could potentially reflect a decreased level of activation for classical, compared to radial categories. Some studies have shown activity in the posterior middle temporal gyrus associated with the retrieval of object properties (Martin, 2007). Hypothetically, such process would be more effortful in radial categories where the relationship between word pairs is based on metaphorical, metonymical and image-schematic mechanisms than in classical categories, where object features are often more obvious.

An important question remains regarding the fact that the level of activation in the right middle temporal gyrus did not differ between homonymic and radial categories. A possible explanation to the lack of differential activation could be that very early in the process of semantic retrieval, homonyms are recognised as two different lexical entries, and therefore, rather than attempting to retrieve properties common to both objects, the meanings of the different lexical entries are accessed.

Comparison of L1 and L2 lexico-semantic access

Several studies have reported that access to L2 words is modulated by proficiency (Jiang, 2001; Abutalebi, 2008), suggesting that in the first stages of learning a second language, access to L2 lexical entries is mediated by access to L1 words. As the learners gain experience in their L2, the process becomes more automatic, to the point at which L2 words are accessed without L1 lexical forms. Sebastian et al. (2011) and Abutalebi & Green (2007) provide support for the aforementioned notion, from a neuroimaging perspective: L2 access is initially a controlled process which becomes more automatic as proficiency in the L2 is acquired. Additionally, while access to L1 is assumed to involve a network of areas mostly localised in the left hemisphere, access to a less proficient L2 involves recruitment of additional areas in the right hemisphere, such as the cingulate, putamen or insula (Meschyan & Hernandez, 2006; Yokohama et al, 2006). Partly in line with these findings, bilinguals showed more activation overall than monolinguals in a number of brain regions: right inferior and middle occipital gyri, right middle temporal gyrus, right precuneus, right angular gyrus and left fusiform gyrus. As mentioned earlier, left fusiform gyrus – the visual word form area- is assumed to host representations of letters, and it has been hypothesised to connect with regions involved in lexico-semantic processing

(Cohen et al, 2003). Activity in the left, rather than the right frontal gyrus has been associated with resolution of competition for the retrieval of different possible meanings of words (Zempleni et al, 2007; Grindrod et al., 2008). However, the activation shown in the right frontal regions is in line with previous studies with brain damage patients that right frontal regions are recruited in order to compensate for damage to the left frontal regions (Winhuisen et al., 2007). Activity in the right frontal area has also been shown in ADHD patients performing a stroop task (Bush, 1999). These findings provide support for the notion that the right frontal areas adopt a compensatory role. Several studies with healthy bilingual participants have also provided evidence of activation in the right frontal lobe associated with processing of less proficient L2 (Meschyan & Hernandez, 2006; Sebastian et al., 2011).

Summary

Summarising , the results of the present study confirm the hypotheses drawn in he previous experimental chapters. In particular, the present results confirm the notion that the relationship between semantic and conceptual knowledge relies on different neural mechanisms. There appears to be three distinct brain areas involved in the processing of the stimuli used. On the one hand, words that entail access to a single core meaning, and to very concrete aspects of the category (classical categories that denote natural objects such as animals) rely on the left hemisphere, specifically, in left occipital areas. Words that involve access to different meanings (homonyms) are associated with activity in right occipital regions, and processing of words that require access to different senses within a single meaning are associated with activity in right middle temporal gyrus. In regards to radial categories, the increased level of activation found, relative to classical categories confirms the hypothesis formulated in chapters 6 and 7, where we hypothesized that increased reaction times and increased N400 amplitude relative to classical and homonymic categories is an indicator of increased cognitive effort. A synthesis of the experimental results will follow in the general discussion.

Chapter 9

General Discussion

The present thesis aimed at exploring three different issues: First, the behavioural and neural correlates of classical categories (as defined in the classical view on categorisation), homonyms (different meanings that have come to be designated under the same word form) and radial categories (as defined in the cognitive linguistics literature). The second topic explored in the present thesis is the relationship between language and thought, in particular, by comparing the processing of categories that are lexicalised in one language (Spanish) but not in the other (English). The last topic addressed in the present thesis is whether there are substantial differences in the representation and processing of categories in bilingual (late L2) speakers compared to native monolingual speakers of English. Given that three of the four studies involved lexical processing (i.e. reading), and participants were both L1 and L2 speakers of English, a secondary goal of the present thesis is to explore L1 and L2 lexical access.

9.1 Behavioural And Neural Correlates Of Classical, Homonymic And Radial Category Processing.

The motivation behind the study of behavioural and neural correlates of classical, homonymic and radial categories was to help bridge the gap that exists between Cognitive Psycholinguistics and Neuroscience. While Cognitive Psycholinguistics approaches have, so far, not been informative about the neural organization of semantic and conceptual knowledge, the vast majority of research in Language Neuroscience has tended to confound semantics and concepts.

Much research in Neuroscience is focused on categories that fit the "classical" view where category membership is determined by the possession of a common set of features. This view is mostly grounded on the notion that there is no division between conceptual and semantic levels of representation –a notion that, as stated in the introductory chapters, stems from a predominantly monolingual perspective-. However, research in Cognitive Linguistics has provided support for the division between conceptual and semantic levels of organisation (see chapter two for a more extensive discussion), and has shown that classical categories are in fact, a small subset of the categories commonly used by us humans, and that the most common type of category structure is radial.

The present research aims to provide information about the processing and representation of different category types and also to provide evidence for the distinction between a level of representation corresponding to semantic knowledge (word meaning) and conceptual knowledge.

Hypotheses

In light of the results of Viñas-Guasch's unpublished master thesis (see chapter five), it was hypothesised that the difference in performance in correctly choosing items that were of the same kind, or 'like' the category exemplar was due to the differences in how semantic information is related to conceptual information about the category. Classical categories were seen as the type of categories where members were the most similar conceptually: members of classical categories tend to share visual or functional features, so the similitude between category members is obvious, even if the different category members are not lexicalised in one word. For instance, a *clock* and a *watch* share both visual and functional features, and it is easy for an English speaker to see the relationship between them, even if English does not lexicalise these meanings in one word (as Spanish does with the word *reloj*). In this sense, classical categories can be seen as meanings (semantic information) mapping onto a single representation in the conceptual system.

Homonymic stimuli were not categories in the same sense as classical (or radial) categories. In fact, homonyms could be seen as an extreme type of category where the meanings designated by a certain word form are completely unrelated. The relationship between the different meanings of homonyms words is arbitrary, so semantic information does not map onto a single representation in the conceptual system. For instance, an English speaker would fail to see the relationship between *wrist* and *doll*, whereas a Spanish speaker could refer to both meanings by using the word form *muñeca.*

Radial categories with taxonomic links were seen as resembling classical categories to a certain extent. The relationship between category members (the "core" sense and the extended senses) is based on projecting or applying certain functional or visual similarities of the core sense onto the extended sense, and as a result, this relationship is not quite as obvious as in classical categories: for instance, to see the relationship between a *beak* and a *pickaxe* (Spanish: *pico*), one has to pay attention to the fact that the specific way in which birds move their beaks is quite similar to the way a human would use a pickaxe (strike it against something in both cases). In the case of radial taxonomic categories, it was hypothesised the different senses of a radial category would map onto different conceptual representations, but there would be a certain degree of overlapping between these (in contrast to homonyms, where the two conceptual representations would be completely separate).

The nature of radial thematic categories was not completely clear. There was the possibility that the different senses of the category would be connected to different conceptual representations. The type of relation between senses in radial thematic categories is qualitatively different to that of radial taxonomic categories, so the degree of overlap could be higher or lower than in the case of radial taxonomic categories.

Behavioural results

All four studies examined differences in classical, homonyms and radial categories. However, the category membership judgment study (chapter five) presented some particularities that distinguished it from the rest of the studies, in terms of the task used (it was the only experiment with visual stimuli) and in terms of the language groups used: the bilingual group consisted of early Catalan-Spanish bilinguals, who were proficient in both languages at a native level, and the monolingual group consisted of native Spanish speakers who did not speak any other languages. For this reason, any findings relating to the effect of bilingualism in the fifth chapter cannot be directly compared to the other chapters, although the findings concerning different category types can compared, since the nature of the categories was practically the same in all studies.

The results of the category membership study support our assumptions about the nature of categories: It was predicted that classical categories would be associated with the highest percentage of correct responses (correctly identifying members of the category). As classical categories are hypothesised to be based upon common visual and functional features, the nature of the task (observe pictures of things) eased the behavioural responses on classical categories. We can hypothesise that when no labels were presented alongside the category exemplars, (in the non label condition), participants could correctly make their category membership judgments accessing conceptual information about the category, without the need to access the semantic representation. On the other hand, performance in homonyms was the lowest of all categories, consistent with the notion that identification of both category members required access to both word meanings.

Radial taxonomic categories followed the pattern of classical categories, and thus percentage of correct responses was second-highest. However, radial thematic categories were associated with a similar level of performance to the homonym group, which suggests that there is little, if any, overlap between conceptual representations of the different senses of the category.

The category membership judgment study showed that highest performance, in terms of percentage of correct responses occurred in classical categories in both the bilingual and the monolingual groups, while performance was lowest in homonyms and radial thematic categories, and radial taxonomic categories occupied an intermediate position.

However, the results of the priming study (sixth chapter) were not entirely consistent –at least not initially- with the findings of the category membership study: classical categories (lexicalised in Spanish in one word, corresponding to two words in English) did not show significantly (different) reaction times than the radial categories, while reaction times for homonyms were significantly faster than the other category types. A striking finding was that, contrary to our predictions, categories in the control condition (two words in both Spanish and English) were associated with faster reaction times than s_wide stimuli across the board, except for classical categories. Classical categories in the control condition showed the slowest reaction times throughout the task.

The behavioural fMRI data (chapter eight) supported (if we consider RT and % of correct responses to be indicators of "ease" of processing) the findings of the category membership judgment study: for both bilinguals and monolinguals, classical categories were the only categories that were processed faster in the s_wide than in the control condition. Moreover, in the bilingual group, only in the s_wide condition had a higher rate of correct responses (83% vs 63% of the related controls), and the lowest percentage of errors (2.34% vs 12%), also least omissions.

Regarding radial categories and homonyms, there were no significant differences between s_wide and controls conditions in terms of RT, but a striking pattern happened in percentages of correct responses both in homonyms, where percentage of CORRECT responses was higher in the control than in the s_wide condition (homonyms: 79% s_wide, 82% controls; radial: 75% vs 85%).

Category types were also examined in the priming study (Chapter six). Stimuli in the control condition were processed faster than in the s_wide condition in radial (taxonomic and thematic) categories and in homonyms, but not in classical categories. In classical categories, items in the control condition were processed considerably slower than in the s_wide condition (rather that s_wide being processed faster).

Imaging Results

The experiments in chapter seven (ERP) and chapter 8 (fMRI) aimed at using neuroimaging techniques in order to explore the brain mechanisms involved in the processing and representation of classical, homonymic and radial categories. In particular, the ERP semantic decision study focused on semantic processing and access to L1 while the fMRI study focused on brain activation patterns for each category type.

Given that there is no previous literature that matches the fMRI study conducted in the present thesis, the present study was mainly exploratory. However, clear differences in patterns of activation between categories were shown: First, all categories were associated with activity in brain areas hypothesised to be involved in the "semantic network" (declarative memory, representation of conceptual knowledge, naming, language switching and so forth). As discussed earlier, the pattern of activation associated to classical categories is consistent with the notion that these categories are the most reliant on a set of features that define a "core", superordinate meaning. (left inferior and medial occipital regions). Homonymic categories were similar to classical categories in that areas in the occipital lobe are recruited, but in this case, in the right hemisphere (middle and occipital areas). Additional activation associated to homonyms was recorded in left hippocampal gyrus, left hypocampus and tail of the caudate nucleus, areas that have been associated with the representation of conceptual knowledge, naming tasks, word finding and involvement in semantic decision task of unrelated word pairs. Taken together, the behavioural and imaging results support the hypothesis of homonymic categories involving access to two separate semantic representations (which would be reflected in increased activity in brain areas associated with semantic representation).

Finally, in contrast to classical categories, activation during the processing of radial categories was mostly concentrated in the right posterior middle temporal gyrus, an area that has been hypothesized to be involved in retrieval of object features. However, activation in the right pMTG did not differ between radial and homonymic categories.

Radial categories differed from both classical and homonyms in that activation was localized only to the right middle temporal gyrus. However, chapter five showed no improvement in radial categories in performance associated with the presence of a label (in a category membership judgement task). Furthermore, the behavioural priming study (chapter six) provided evidence for slower RTs in processing of radial categories compared to the other category types. Finally, in the ERP semantic decision study, radial categories were associated with larger N400 amplitudes than related controls. Altogether, the behavioural, fMRI and

ERP data show that processing of radial categories yield a pattern of activation somewhat similar to homonym processing, although processing of radial categories is more effortful than either classical or homonymic categories. Increased RTs and N400 amplitude suggest that, while in the case of homonyms, both word meanings are retrieved early during category processing (which does not necessary imply conceptual access), the cognitive effort associated with radial categories might reflect an effort to integrate or the two senses of the category or to deduct the relationship between these.

9.2 Study Of The Relationship Between Language And Thought: Lexicalised And Non-Lexicalised Categories

The study of lexicalised categories (categories that can be designated with one word in a certain language), compared to non-lexicalised categories can provide an insight on whether language influences the nature of or concepts. In this sense, chapter five (category membership study) directly examined the influence of the presence of a linguistic label on participants' judgements on category membership, while in chapter eight (fMRI study), we indirectly examined (via the L2) the neural and behavioural correlated of lexical decision of lexicalized and non-lexicalised categories.

Behavioural results

In chapter five, a group of participants performed the category membership task while they were shown a label naming the superordinate category, in conjunction with a picture of the superordinate category. In the other group, no label was shown. The effect of presenting a word describing the superordinate category can be thought of as an “online” effect of language: percentage of category congruent responses (indicating category exemplars within category boundaries) was highest across all category types when the label was present. The exception was radial thematic categories, where performance in the absence of a label decreased).

These results contradict theories that presuppose that language and cognition are separate systems. However, further evidence for the interrelation between language and though is given by the results of chapter eight (fMRI).

Imaging results

In bilingual participants, control stimuli, but not lexicalized stimuli were associated with activity in right putamen, right globus pallidus and right lentiform nucleus. Structures in the right hemisphere (putamen, cingulate gyrus, insula) have been associated with access to a less proficient L2. In the present study, the activitation of the right putamen associated to the processing of non-lexicalised (control) stimuli, and the absence of activity in these areas when processing lexicalized stimuli might indicate reduced access to the L2, but increased access to the L1 in lexicalized stimuli, consistent with the fact that categories were lexicalized in the L1 (Spanish) but not in the L2 (English), as the stimuli presented to the bilingual participants was in their L2.

The findings on the relationship between language and thought relate to the issue of whether there is L1 access in linguistic tasks in the L2. This issue will be addressed in the next section.

9.3 Category Processing And Representation In Late L2 And Native Monolingual Speakers

As we stated earlier, the differences observed in processing of different category types and between lexicalized and non-lexicalised stimuli seem to be related to the fact that word meaning in the semantic system relates to the conceptual system in a non-uniform manner (i.e. certain category types are more reliant on the semantic system and certain types rely more on the conceptual system).

However, the fact that the studies here reviewed utilized both native English speakers who performed the studies using their L1, and late bilinguals (who used their L2 throughout the studies) brings in the question of whether the bilingual category system (built upon multiple semantic system) differs from the monolingual category system (built upon one category system).

Behavioural results

The category membership study (chapter five) tested both monolingual and bilingual samples on the same stimuli, where each language group was presented with the linguistic stimuli in their own L1. By examining participants' judgments on category membership, it was possible to draw conclusions on the nature of their category system.

Overall, bilinguals performed better across the board, in both Viñas-Guasch's unpublished masters thesis and in the study presented in chapter five. In particular, when the task specified the superordinate category (with a label), bilinguals identified the other category members in a higher percentage of trials than monolinguals. This effect can be taken as an indication of either a bilingual semantic system that is different from the monolingual category system (for instance, where category members have a higher degree of default activation than in the monolingual category system) or a more exhaustive processing of the list of all possible category exemplars. However, the other studies in this thesis employed late bilingual speakers performing the tasks in their L2. In this case, the question arises of whether the L2 semantic system is mediated by the L1, or whether there are two independent semantic systems, one for the L1 and one, less proficient, for the L2.

Imaging results

The issue of L1 access in L2 tasks was addressed in the ERP study (chapter six). The ERP study confirmed that access to the L1 semantic system takes place when processing classical categories, given that there were no differences when processing related and classical categories in bilinguals. If bilinguals did not access their L1 classical categories, a pattern of performance similar to that of the monolingual group would be expected (i.e. smaller N400 amplitudes for related stimuli than for S_wide stimuli). Evidence for access to the L1 In homonyms, lies in the observed larger N400 amplitude for unrelated controls than for S_wide items (again, if no access to L1 was involved, N400 amplitudes would be similar between unrelated controls and homonyms).

However, there is no such evidence in the case of radial categories. In the bilingual group, N400 amplitude was larger for radial categories than related controls. We can hypothesise that the effect might be due to processing of a combination of radial categories with thematic and taxonomic links, which would imply access to the L1 in some, but not all categories. Alternatively, it is possible that radial thematic categories are seen as having a higher degree of relatedness than radial taxonomic categories.

While it is clear that English meanings which are unrelated in monolingual English speakers are “more related” in bilinguals, there is no clear explanation on the nature of this phenomenon. On the one hand, the increase in relatedness of the L2 meanings could be due to a developmental process in which the meanings become more related through interaction between conceptual “reconfiguration” and linguistic acquisition (even later in life), or an “online” effect of L1 relatedness carrying into the L2. The latter explanation would account for the fact that in the bilingual group, but not in the monolingual group, there was a larger N400 amplitude in unrelated stimuli, compared to homonyms.

9.4. Implications For Current Models Of Bilingual Lexical Processing

The empirical evidence here reviewed poses implications for the current models of lexical processing. In particular, we propose a revision of Pavlenko’s 2009 MHM (Modified Hierarchical Model). The original MHM model which aimed to address the issue of a lexicon composed by L1 and L2 words. However, the MHM does not specify whether category types are uniform or different (see figure 9.1).

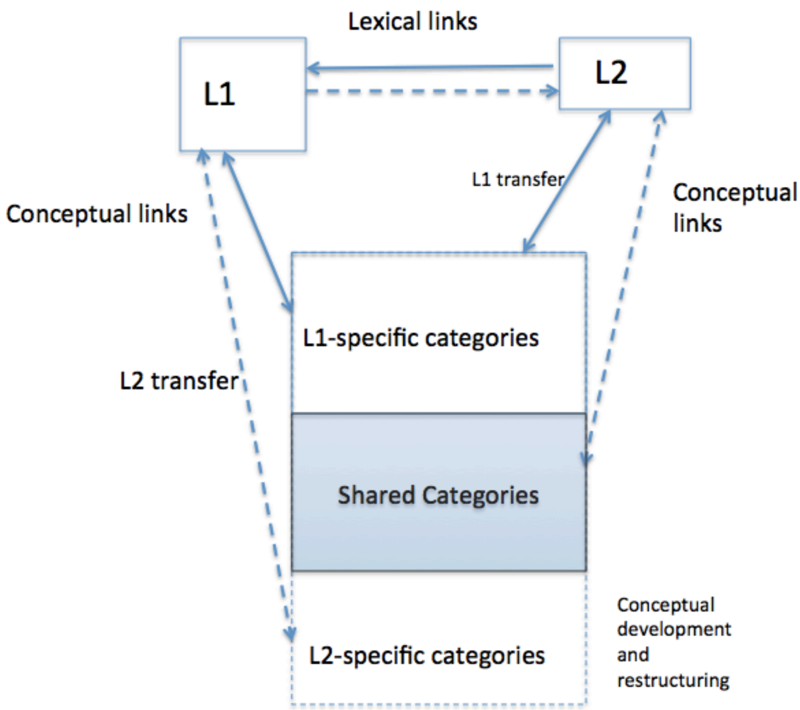


Figure 9.1. Modified hierarchical model (Pavlenko, 2009)

The evidence of the present research suggests that categories are not uniform and that they link to semantic and conceptual systems in different ways. Additionally, members of categories that are lexicalized in one of the languages and not in the other language can still present a high degree of relationship, and this degree of relationship is even higher when the other language places them together in the same category. Taken together the evidence supporting classical categories' reliance on the conceptual system and homonyms on the semantic system, we can propose a revision of the MHM that can be applied to late bilingual speakers (see figure 9.2).

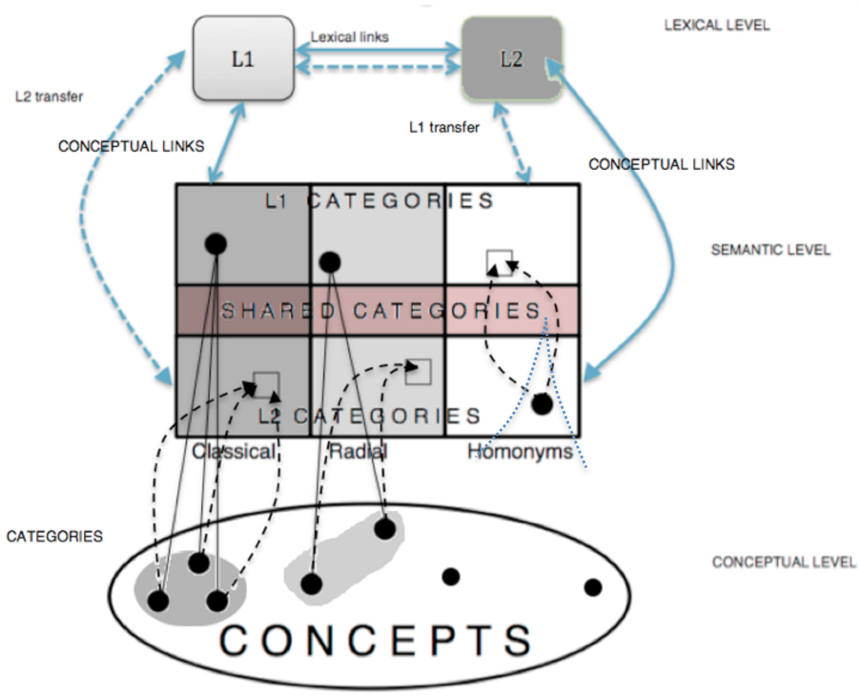


Figure 9.2. Revision to the MHM, in order to account for different category types, and adapted for late bilinguals.

The modification to the MHM that we propose introduces the notion of a semantic level hosting different types of categories (classical, radial and homonymic) instead fo a single type of category. Each semantic category member maps onto a conceptual equivalent. The distance between members in the model refects the hypothesised conceptual difference between category members, where members of the same classical category are conceptually closer (more visually and functionally similar) than members of radial categories. Under this model, Homonyms would not map onto the conceptual space as the other category types, but rather, each category member would have a correspoding conceptual representation. Finally, the model reflects the empirical evidence suggesting that categories lexicalised in one language bring concepts closer in the conceptual space. In this case, L1 lexicalised categories would have a corresponding L2 semantic representation (grey boxes in the L2 semantic system), although these would not be as strong as the L1 categories.

As mentioned earlier, due to the lack of previous research addressing the distinction between classical categories and categories built on language mechanisms, the present research was mostly exploratory.

To our knowledge this thesis is the first body of work that provides both behavioural and neuroimaging comparisons of the different mechanisms involved in the processing of classical, homonymic and radial categories, by exploring how this process occurs in the monolingual and bilingual category systems. Additionally, the present research yields light on the nature of the relationship between language and thought, by providing evidence on how different category types draw differentially on the conceptual and semantic systems.

Future Research

Some of the previous research reviewed in the present thesis examined the processing of words with multiple meanings (Grindrod et al., 2008; Kleposniotou et al., 2012; Whitney et al., 2010), while other studies compared retrieval of L1 and L2 lexical and semantic knowledge (Abutalebi & Green, 2007). Nevertheless, the present research is unique in that is the first to compare, using neuroimaging techniques, categories that follow the "classical" notion and categories are build on commonality, and categories that result from language mechanisms. However, there are some limitations to the present research. A limiting factor to cross linguistic research comparing category types that are lexicalised in one language, but not in the other lies precisely in the stimuli. As shown in the present research, while it is possible to match the stimuli in parameters that can affect RT, N400 or BOLD signal effects such as word frequency and length, imageability, concreteness and percentage of cognates in L1 and L2, a serious limitation resides in the fact that, to our knowledge, there are no standardised norms for word relatedness, or in other words, there are no measures of word co-occurrence. Some researchers use the number of "hits" in the Google search engine when searching for word pairs (i.e. Goose – Blackberry), a method that is flawed in that the hits do not take into account the sense of the word (Google does not make a distinction between the sense of *blackberry* a fruit or *blackberry* a mobile phone), and still raises the question of how precise internet word frequency is, when taken as an indicator of human language word frequency (as compared to established corpuses).

Besides the limitations highlighted above, priming, ERP and fMRI follow-up studies replicating the present research could provide further knowledge on the interrelation between L1 and L2 by using an early bilingual Spanish-English population It could be that no access to L2.

References

Abutalebi, J. (2008). Neural aspects of second language representation and language control. *Acta psychologica*, *128*(3), 466–78.

Abutalebi, J., & Green, D. (2007*).* Bilingual language production: The neurocognition of language representation and control. *Journal of Neurolinguistics* (Vol. 20, pp. 242–275).

Aizenstein, H. J., MacDonald, a W., Stenger, V. a, Nebes, R. D., Larson, J. K., Ursu, S., & Carter, C. S. (2000). Complementary category learning systems identified using event-related functional MRI. *Journal of cognitive neuroscience*, *12*(6), 977–87.

Allport, D.A. (1985). Distributed memory, modular systems and dysphasia. In Newman, S.K. and Epstein, R. (Eds.). *Current Perspectives in Dysphasia.* Edinburgh: Churchill Livingstone.

Ameel, E., Malt, B. C., Storms, G., & Van Assche, F. (2009). Semantic convergence in the bilingual lexicon. *Journal of Memory and Language*, *60*(2), 270–290.

Ameel, E., Storms, G., Malt, B. C., & Sloman, S. a. (2005). How bilinguals solve the naming problem. *Journal of Memory and Language*, *53*(1), 60–80.

Arias-Trejo, N., & Plunkett, K. (2010). The effects of perceptual similarity and category membership on early word-referent identification. *Journal of experimental child psychology*, *105*(1-2), 63–80.

Barsalou, L. W. (2003). Abstraction in perceptual symbol systems. *Philosophical transactions of the Royal Society of London.* Series B, Biological sciences, *358*(1435), 1177–87.

Barsalou, L. W. (2008a). Grounded cognition. *Annual review of psychology*, *59*, 617–45.

Barsalou, L. W. (2008b). Cognitive and Neural Contributions to Understanding the Conceptual System. *Current Directions in Psychological Science*, *17*(2), 91–95.

Beauchamp, M. S., and Martin, A. (2007). Grounding object concepts in perception and action: evidence from fMRI studies of tools. *Cortex* 43:461-468.

Beauvois, M. F. (1982). Optic aphasia: A process of interaction between vision and language. *Proceedings of the Royal Society of London, Series B*, *298*, 35–47.

Berlin, B., & Kay, P. (1969). Basic color terms: Their universality and evolution. Berkeley: *University of California Press*.

Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development* 70, no. 5: 636-644.

Binder J.R., Desai R.H., Graves W.W., Conant L.L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cerebral Cortex.* 19, 2767-2796.

Bloom, P., & Keil, F. C. (2001). Thinking Through Language. *Mind and Language*, *16*(4), 351–367.

Bookheimer S. (2002). Functional MRI of language: new approaches to understanding the cortical organization of semantic processing. *Annual Review of Neuroscience* 25:151–188.

Bowerman, M. (1996). The origins of children's spatial semantic categories: Cognitive versus linguistic determinants. In J. J. Gumperz & S. C. Levinson (Eds.), *Rethinking linguistic relativity* (pp. 145–176).

Bowerman, M. and Choi, S. (2001). Shaping meanings for language: universal and language-specific in the acquisition of spatial semantic categories. In M. Bowerman and S. C. Levinson (Eds) *Language acquisition and conceptual development*, (pp. 475-511). Cambridge: Cambridge University Press.

Broca, P. (1863). Localisations des fonctions cérébrales. Siège de la faculté du langage articulé. *Bulletin de la Société d'Anthropologie.* 4: 200–208.

Bueno, S., & Frenck-Mestre, C. (2008). The activation of semantic memory: Effects of prime exposure, prime-target relationship, and task demands. *Memory & Cognition*, *36*(4), 882–898.

Burgess, C., & Simpson, G. B. (1988). Cerebral hemispheric mechanisms in the retrieval of ambiguous word meanings. *Brain and language*, *33*(1), 86–103.

Bush, G., Frazier, J. A, Rauch, S. L., Seidman, L. J., Whalen, P. J., Jenike, M. A, Rosen, B. R., et al. (1999). Anterior cingulate cortex dysfunction in attention-deficit/hyperactivity disorder revealed by fMRI and the Counting Stroop. *Biological psychiatry*, *45*(12), 1542–52.

Buxbaum, L. J., & Kalénine, S. (2010). Action knowledge, visuomotor activation, and embodiment in the two action systems. *Annals of the New York Academy of Sciences*, 1191, 201–18.

Cabeza, R., & Nyberg, L. (2000). Imaging cognition II: An empirical review of 275 PET and fMRI studies. *Journal of cognitive neuroscience*, *12*(1), 1–47.

Caramazza, A., & Mahon, B. Z. (2006). The organisation of conceptual knowledge in the brain: The future's past and some future directions. *Cognitive neuropsychology*, *23*(1), 13–38.

Caramazza, A., & Shelton, J. R. (1998). Domain-specific knowledge systems in the brain: The animate-inanimate distinction. *Journal of Cognitive Neuroscience*, 10, 1-34.

Chwilla, D. J., Kolk, H. H., & Mulder, G. (2000). Mediated Priming in the Lexical Decision Task: Evidence from Event-Related Potentials and Reaction Time. *Journal of Memory and Language*, *42*(3), 314–341.

Clark, H. H. (1996b). Communities, commonalities, and communication. In J. Gumperz & S. C. Levinson (Eds.), *Rethinking linguistic relativity*, 17, 324–355. Cambridge University Press.

Cohen, L. (2003). Visual Word Recognition in the Left and Right Hemispheres: Anatomical and Functional Correlates of Peripheral Alexias. *Cerebral Cortex*, *13*(12), 1313–1333.

Coltheart, M. (1981). The MRC Psychologuistics database. *Quarterly Journal of Experimental Psychology*, *33*, 497–505

Coltheart, V., Laxon, V. J., Keating, C. (1988). Effects of word imageability and age of acquisition on children's reading. *British Journal of Psychology,* 79, 1-12.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, *82*(6), 407–428.

Cook, V.J., Bassetti, B., Kasai, C., Sasaki, M. & Takahashi, J.A. (2006), 'Do bilinguals have different concepts? The case of shape and material in Japanese L2 users of English', *International Journal of Bilingualism,* 2, 137-152.

Costa, A., Colomé À., & Caramazza A. (2000). Lexical Access in Speech Production: The Bilingual Case. *Psicológica*. 21, 403-437.

Crinion J., Turner R., Grogan A., Hanakawa T., Noppeney U., Devlin J. T., Aso T., Urayama S., Fukuyama H., Stockton K., Usui K., Green D. W., Price C. J. (2006).

Language control in the bilingual brain. *Science (New York, N.Y.)*, *312*(5779), 1537–40.

Crutch S.J., Warrington E.K. (2003). The selective impairment of fruit and vegetable knowledge: A multiple processing channels account of fine-grain category specificity. *Cognitive Neuropsychology*, 20(3-6), 355 - 372.

Damasio H., Grabowski T.J., Tranel D., Hichwa R.D., Damasio A.R. (1996). A neural basis for lexical retrieval. *Nature*. 380:499–505

Damasio H., Grabowski T., Frank R., Galaburda A.M., Damasio A.R. (1994). "The return of Phineas Gage: clues about the brain from the skull of a famous patient". *Science* 264 (5162): 1102–5.

De Bot, K. (2004). The Multilingual Lexicon : Modelling Selection and Control The Multilingual Lexicon : Modelling Selection and Control. *International journal of multilingualism*, (December 2012), 37–41.

Deacon, D., Hewitt, S., Yang, C.M., & Nagata, M. (2000). Event-related potential indices of semantic priming using masked and unmasked words: evidence that the N400 does not reflect a post-lexical process. *Cognitive Brain Research*, *9*(2), 137–146.

Dijkstra, T., & van Heuven, W. V. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition*, *5*(03).

Dijkstra, T., & van Heuven, W. V. (2006). On Language and the Brain—Or on (Psycho) linguists and Neuroscientists? Commentary on Rodriguez-Fornells et al. *Language Learning*, 191–198.

Dunn, L. M., Dunn, D. M., Whetton, C., & Burley, J. (1997). British Picture Vocabulary Scales (second edition). NFER-Nelson, Windsor.

Elman, J. L. (2009). On the meaning of words and dinosaur bones: Lexical knowledge without a lexicon. *Cognitive science*, *33*(4), 547–582.

Elman, J. L. (2011). Lexical knowledge without a lexicon? *The mental lexicon*, *6*(1), 1–33.

Estes, Z., Golonka, S., & Jones, L. L. (2011). Thematic thinking: The apprehension and consequences of thematic relations (pp. 249-294). In B. Ross (Ed.), *Psychology of Learning and Motivation*, Vol. 54. Burlington: Academic Press.

Estes, Z., & Jones, L. L. (2009). Integrative priming occurs rapidly and uncontrollably during lexical processing. *Journal of experimental psychology. General*, *138*(1), 112–30.

Fazio, R. H., Williams, C. J., & Powell, M. C. (2000). Measuring associative strength: Category-item associations and their activation from memory. *Political Psychology*, 21, 7-25

Fodor, J. (1975). *The language of thought*. (Cromwell, Ed.). New York.

Fodor, J. A. (1983). *The Modularity of Mind: An Essay on Faculty Psychology*. *A Bradford book* (Vol. 60, p. 145). MIT Press.

Forster, K. I. (1998). The pros and cons of masked priming. *Journal of psycholinguistic research*, *27*(2), 203–33.

Francis, W. S. (2005). Bilingual Semantic and Conceptual Representation. In J F Kroll & A. M. B. De Groot (Eds.), *Handbook of bilingualism Psycholinguistic approaches* (pp. 251–267). Oxford University Press.

Freund, C.S. (1889). Uber optische Aphasie und Seelenblindheit. *Archiv. Psychiatrie Nervenkr., 20:276-297,* 371-416,

Gallese, V., & Lakoff, G. (2005). The Brain's concepts: the role of the Sensory-motor system in conceptual knowledge. *Cognitive neuropsychology*, *22*(3), 455–79.

Gathercole, V. C. M. (in preparation). Word meaning.

Gathercole, V. C. M. (2006). Introduction to Special Issue: Language-specific influences on acquisition and cognition. *First Language*, *26*(1), 5–17.

Gathercole, V.C.M., Thomas, E.M., Jones, L., Viñas-Guasch, N., Young, N., & Hughes, E.K. (2010). Cognitive effects of bilingualism: digging deeper for the contributions of language dominance, linguistic knowledge, socio-economic status and cognitive abilities. *International Journal of Bilingual Education and Bilingualism.* 13, (5) 617-664.

Gathercole, V.C.M., & Moawad, R.A. (2010). Semantic interaction in early and late bilinguals: All words are not created equally. *Bilingualism: Language and Cognition*, *13*(04), 385–408.

Geyer, A., Holcomb, P. J., Midgley, K. J., & Grainger, J. (2011). Processing words in two languages: An event-related brain potential study of proficient bilinguals. *Journal of neurolinguistics*, *24*(3), 338–351.

Glaser, W. R., & Düngelhoff, F. J. (1984). The time course of picture-word interference. *Journal of experimental psychology. Human perception and performance*, *10*(5), 640–54.

Goebel, R., Esposito, F., Formisano, E. (2006). Analysis of FIAC data with BrainVoyager QX: from single-subject to cortically aligned group GLM analysis and self-organizing group ICA. *Human. Brain Mapping*. 27 (5), 392–401.

Grafton, S. T., Arbib, M. A., Fadiga, L., & Rizzolatti, G. (1996). Localization of grasp representations in humans by PET: 2. Observation compared with imagination. *Experimental Brain Research*, 112, 103–111.

Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological Review, 103,* 518–565.

Grosjean, F., Li, P., Münte, T. F., & Rodriguez-Fornells, A. (2003). Imaging bilinguals: When the neurosciences meet the language sciences. *Bilingualism: Language and Cognition*, *6*(2), 159–165.

Grossman, M., Koenig, P., DeVita, C., Glosser, G., Alsop, D., Detre, J., & Gee, J. (2002). The neural basis for category-specific knowledge: an fMRI study. *NeuroImage*, *15*(4), 936–48.

Grossman, M., Smith, E. E., Koenig, P., Glosser, G., DeVita, C., Moore, P., & McMillan, C. (2002). The Neural Basis for Categorization in Semantic Memory. *NeuroImage*, *17*(3), 1549–1561.

Gärdenfors, P.: (1996) Conceptual spaces as a basis for cognitive semantics. (In: Clark, A., et al. eds.) *Philosophy and Cognitive Science*, pp. 159–180. Kluwer, Dordrecht.

Hagoort, P., Hald, L., Bastiaansen, M., & Petersson, K. M. (2004). Integration of word meaning and world knowledge in language comprehension. *Science*, *304*, 438–441.

Hampton, J. A. (2007). Typicality, graded membership, and vagueness. *Cognitive science*, *31*(3), 355-384.

Hart, J., & Gordon, B. (1992). Neural subsystems for object knowledge. *Nature*, 359: 60–64.

Hernandez, A.E., Bates, E.A., & Avila, L.X. (1996). Processing across the language boundary: a cross-modal priming study of Spanish-English bilinguals. *Journal of experimental psychology. Learning, memory, and cognition*, *22*(4), 846–64.

Hernandez, A.E., & Reyes, I. (2002). Within- and between-language priming differ: Evidence from repetition of pictures in Spanish-English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*(4), 726–734.

Jackendoff, R. (2002). *Foundations of Language*. *Program* (pp. 1–18). Oxford University Press.

Jarvis, S., & Pavlenko, A. (2008). *Crosslinguistic Influence in Language and Cognition*. New York: Routledge.

Ji, L.-J., Zhang, Z., & Nisbett, R. E. (2004). Is it culture or is it language? Examination of language effects in cross-cultural research on categorization. *Journal of personality and social psychology*, *87*(1), 57–65.

Jiang, N. (2000). Lexical representation and development in a second language. *Applied Linguistics*, *21*(1), 47–77.

Juffs, A. (2009). The second language acquisition of the lexicon. In W. Ritchie & T.K. Bhatia, (eds*). The New Handbook of Second Language Acquisition*. Leeds, UK. Emerald.

Kalénine, S., Bonthoux, F., & Borghi, A. M. (2009). How action and context priming influence categorization: A developmental study. *The British journal of developmental psychology*, *27* (3), 717–30.

Kalénine, S., Peyrin, C., Pichat, C., Segebarth, C., Bonthoux, F., & Baciu, M. (2009). The sensory-motor specificity of taxonomic and thematic conceptual relations: a behavioral and fMRI study. *NeuroImage*, *44*(3), 1152–62.

Kan, I. P., Barsalou, L. W., Solomon, K. O., Minor, J. K., & Thompson-Schill, S. L. (2003). Role of mental imagery in a property verification task: FMRI evidence for perceptual representations of conceptual knowledge. *Cognitive neuropsychology*, *20*(3), 525–40.

Katz, J., & Fodor, J. (1963). The structure of a semantic theory. *Language*, *39*(2), 170–210.

Kempen, G., & Huijbers, P. (1983). The lexicalization process in sentence production and naming: indirect election of words. *Cognition*, *14*(2), 185–209.

Kerkhofs, R., Dijkstra, T., Chwilla, D. J., & de Bruijn, E. R. A. (2006). Testing a model for bilingual semantic priming with interlingual homographs: RT and N400 effects. *Brain research*, *1068*(1), 170–83.

Khateb, A., Michel, C. M., Pegna, A. J., Thut, G., Landis, T., & Annoni, J. M. (2001). The time course of semantic category processing in the cerebral hemispheres: an electrophysiological study. *Brain research. Cognitive brain research*, *10*(3), 251–64.

Kiefer, M., Weisbrod, M., Kern, I., Maier, S., & Spitzer, M. (1998). Right hemisphere activation during indirect semantic priming: evidence from event-related potentials. *Brain and language*, *64*(3), 377–408.

Kilgarriff, A. (1995), BNC database and word frequency lists. Available online at <http://www.kilgarriff.co.uk/bnc-readme.html>.

Kircher, T., Sass, K., Sachs, O., & Krach, S. (2009). Priming words with pictures: neural correlates of semantic associations in a cross-modal priming task using fMRI. *Human brain mapping*, *30*(12), 4116–28.

Kroll, J. F., Sumutka, B. M., & Schwartz, a. I. (2005). A cognitive view of the bilingual lexicon: Reading and speaking words in two languages. *International Journal of Bilingualism*, *9*(1), 27–48.

Kroll, J. F., Van Hell, J. G., Tokowicz, N., & Green, D. W. (2010). The Revised Hierarchical model: A critical review and assessment. *Bilingualism: Language and Cognition*, 13 (3), 373-381.

Kuperberg, G. R., Lakshmanan, B. M., Greve, D. N., & West, W. C. (2008). Task and semantic relationship influence both the polarity and localization of hemodynamic modulation during lexico-semantic processing. *Human brain mapping*, *29*(5), 544–61.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: brain potentials reflect semantic incongruity. *Science*, *207*(4427), 203–205.

Kutas, M, & Federmeier, K. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in cognitive sciences*, *4*(12), 463–470.

Kutas, M. and Van Petten, C. Event-Related Brain Potential Studies of Language. In: P. K. Ackles, J. R. Jennings, and M. G. H. Coles (Eds.). *Advances in Psychophysiology, Volume 3*, Greenwich, Connecticut: JAI Press, Inc., 1988, pp 139-187.

Kutas, Marta, & Federmeier, K. D. (2011). Thirty years and counting: finding meaning in the N400 component of the event-related brain potential (ERP). *Annual review of psychology*, *62*, 621–47.

Lam, K. J. Y., & Dijkstra, T. (2010). Word repetition, masked orthographic priming, and language switching: bilingual studies and BIA+ simulations. *International Journal of Bilingual Education and Bilingualism*, *13*(5), 487–503.

Lambon Ralph, M. A., McClelland, J. L., Patterson, K., Galton, C. J., & Hodges, J. R. (2001). No right to speak? The relationship between object naming and semantic impairment: Neuropsychological abstract evidence and a computational model. *Journal of Cognitive Neuroscience*, 13, 341–356.

Lambon Ralph M.A., Patterson K. (2008). Generalization and Differentiation in Semantic Memory: Insights from Semantic Dementia. *Ann. N.Y. Acad. Sci*, 1124, 61-76

Lambon Ralph M.A., Pobric G.G., Elizabeth Jefferies. (2009). Conceptual knowledge is underpinned by temporal pole bilaterally: Convergent evidence from rTMS. *Cerebral Cortex*, 19.

Lecours, A. R., & Joanette, Y. (1980). Linguistic and Other Psychological Aspects of Paroxysmal Aphasia. *Brain and Language*, (10), 1–23.

Levelt, W. (1999). Models of word production. *Trends in cognitive sciences*, *3*(6), 223–232.

Levinson, S. C. (1997). From outer to inner space: Linguistic categories and non-linguistic thinking. In J. Nuyts, & E. Pederson (Eds.), *Language and conceptualization* (pp. 13-45). Cambridge University Press

Lhermitte, F., & Beauvois, M. (1973). A visual-speech disconnexion syndrome. Report of a case with optic aphasia, agnosic alexia and colour agnosia. *Brain*, 695–714.

Lin, E. L., & Murphy, G. L. (2001). Thematic relations in adults' concepts. *Journal of Experimental Psychology: General, 130,* 3-28.

Liu, C., Tardif, T., Mai, X., Gehring, W. J., Simms, N., & Luo, Y.J. (2010). What’s in a name? Brain activity reveals categorization processes differ across languages. *Human brain mapping*, *31*(11), 1786–801.

Luck, S. J. (2005). *An Introduction to the Event-Related Potential Technique*. (M. Gazzaniga, Ed.). *International Review of Neurobiology* (Vol. 102, p. 374). MIT Press.

Mahon, B. Z., & Caramazza, A. (2009). Concepts and categories: a cognitive neuropsychological perspective. *Annual review of psychology*, *60*, 27–51.

Majid, A., Boster, J. S., & Bowerman, M. (2008). The cross-linguistic categorization of everyday events: a study of cutting and breaking. *Cognition*, *109*(2), 235–50.

Malt, B. C.; Sloman, S. A (2007).: Artifact Categorization. The Good, the Bad, and the Ugly. In: Margolis, E.; Laurence, S. (eds.):*Creations of the Mind. Theories of Artifacts and Their Representation.* Oxford [Oxford University Press], p. 85-124

Malt, B. C., Sloman, S. A., Gennari, S., Shi, M., & Wang, Y. (1999). Knowing versus Naming: Similarity and the Linguistic Categorization of Artifacts. *Journal of Memory and Language*, *40*(2), 230–262.

Mandler, J. M. (2007). On the origins of the conceptual system. *The American psychologist*, *62*(8), 738–51.

Markman, E. M. (1990). Constraints children place on word meanings. *Cognitive Science*, 14, 57-77.

Martin, A. (2001). Functional neuroimaging of semantic memory. (In R. Cabeza & A. A. Kingstone, Eds.) *Handbook of functional neuroimaging of cognition*, *1*(3), 153–186.

Martin, A. (2007). The representation of object concepts in the brain. *Annual review of psychology*, *58*, 25–45.

Martin A, Ungerleider L.G, & Haxby J.V. (2000).Category-specificity and the brain: The sensory - motor model of semantic representations of objects. *The New Cognitive Neurosciences, 2nd Edition*. Cambridge: MIT Press

Martin, A., Wiggs, C., Ungerleider, L., & Haxby, J. (1996). Neural correlates of category-specific knowledge. *Nature*, 379, 649-652.

Medler, D.A., & Binder, J.R. (2005). MCWord: An On-Line Orthographic Database of the English Language. Http://www.neuro.mcw.edu/mcword/

Meschyan, G., & Hernandez, A. E. (2006). Impact of language proficiency and orthographic transparency on bilingual word reading: an fMRI investigation. *NeuroImage*, *29*(4), 1135–40.

Meyer, D. E., & Schvaneveldt, R. W . (1971). facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology, 90,*227-234

Michael, E. B., & Gollan, T. H. (2005). Being and becoming bilingual. In J. F. Kroll & A. M. B. de Groot (Eds.), *Handbook of bilingualism: Psycholinguistic approaches* (pp. 389–406). Oxford: Oxford University Press.

Midgley, K. J., Holcomb, P. J., & Grainger, J. (2009). Masked repetition and translation priming in second language learners: a window on the time-course of form and meaning activation using ERPs. *Psychophysiology*, *46*(3), 551–65.

Mion, M., Patterson, K., Acosta-Cabronero, J., Pengas, G., Izquierdo-Garcia, D., Hong, Y. T., Fryer, T. D., et al. (2010). What the left and right anterior fusiform gyri tell us about semantic memory. *Brain : a journal of neurology*, *133*(11), 3256–68.

Mitchell, T. M., Shinkareva, S. V., Carlson, A., Chang, K.M., Malave, V.L., Mason, R.A, & Just, M. A. (2008). Predicting human brain activity associated with the meanings of nouns. *Science (New York, N.Y.)*, *320*(5880), 1191–5.

Mummery C.J., Patterson K., Price C.J., Ashburner J., Frackowiak R.S., Hodges J.R. (2000). A voxel-based morphometry study of semantic dementia: the relationship between temporal lobe atrophy and semantic memory. *Annual Journal of Neurology*; 47: 36

Murphy, G. L. (2002). *The Big Book of Concepts*. Cambridge, MA: MIT Press.

Neely, J. H., Keefe, D. E., & Ross, K. L. (1989). Semantic priming in the lexical decision task: roles of prospective prime-generated expectancies and retrospective semantic matching. *Journal of experimental psychology. Learning, memory, and cognition*, *15*(6), 1003–19.

Paivio, A (1971). *Imagery and verbal processes*. New York: Holt, Rinehart, and Winston.

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology*, *45*(3), 255–287.

Paradis, M. (1997). The cognitive neuropsychology of bilingualism. In A. M. B. Groot & J. F. Kroll (Eds.), *Tutorials in bilingualism: Psycholinguistic perspectives* (pp. 331–354). Hillsdale, NJ: Lawrence Erlbaum.

Paradis, M. (2004). *A neurolinguistic theory of bilingualism*. Amsterdam : John Benjamins.

Patterson, K., Nestor, P. J., & Rogers, T. T. (2007). Where do you know what you know? The representation of semantic knowledge in the human brain. *Nature reviews. Neuroscience*, *8*(12), 976–87.

Pavlenko, Aneta. (2000). New approaches to concepts in bilingual memory. *Bilingualism: Language and Cognition*, 2, 209–230.

Pavlenko, Anetta. (2009). *The bilingual mental lexicon: Interdisciplinary approaches*. Clevedon, UK: Multilingual matters.

Perea, M., Duñabeitia, J. A., & Carreiras, M. (2008). Masked associative/semantic priming effects across languages with highly proficient bilinguals. *Journal of Memory and Language*, *58*(4), 916–930.

Petersen, S. E., Fox, P. T., Posner, M. I., Mintin, M., Raichle, M. E. (1988). Positron emission tomographic studies of the cortical anatomy of single-word processing. *Nature*, 331: 585-89

Pinker, S. (1994). *The Language Instinct: How the Mind Creates Language*. *Language* (Vol. 71, p. 610). William Morrow.

Pinker, S. (2007). *The Stuff of Thought: Language as a Window into Human Nature*. *Thought A Review Of Culture And Idea* (Vol. 1, p. 499). Viking.

Pobric, G., Jefferies, E., & Lambon Ralph, M. A. (2010). Amodal semantic representations depend on both left and right anterior temporal lobes: New rTMS evidence. *Neuropsychologia*, 48, 1336–1342.

Pobric, G., Lambon Ralph, M.A., & Jefferies, E. (2009). The role of the anterior temporal lobes in the comprehension of concrete and abstract words: rTMS evidence. *Cortex*, 45(9), 1104-1110.

Pylkkänen, L., Brennan, J., & Bemis, D. K. (2011). Grounding the cognitive neuroscience of semantics in linguistic theory. *Language and Cognitive Processes*, *26*(9), 1317–1337.

Pylyshyn, Z. W. (1981). The imagery debate: Analogue media versus tacit knowledge. *Psychological Review, 87*, 16-45.

Quinn, W. M., & Kinoshita, S. (2008). Congruence effect in semantic categorization with masked primes with narrow and broad categories. *Journal of Memory and Language*, *58*(2), 286–306.

Raposo, A, Moss, H. E., Stamatakis, E. A, & Tyler, L. K. (2006). Repetition suppression and semantic enhancement: an investigation of the neural correlates of priming. *Neuropsychologia*, *44*(12), 2284–95.

Richardson, F. M., Seghier, M. L., Leff, A. P., Thomas, M. S. C., & Price, C. J. (2011). Multiple routes from occipital to temporal cortices during reading. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *31*(22), 8239–47.

Ringbom, H. (2001). Lexical transfer in L3 production. In J. Cenoz, B. Hufeisen, & U. Jessner (Eds.), *Cross-linguistic influence in third language acquisition: Psycho- linguistic perspectives* (pp. 59–68). Clevedon, UK: Multilingual Matters.

Rissman, J., Eliassen, J. C., & Blumstein, S. E. (2003). An event-related FMRI investigation of implicit semantic priming. *Journal of cognitive neuroscience*, *15*(8), 1160–75.

Roberson, D., & Hanley, J.R. (2010). Relatively speaking: An account of the relationship between language and thought in the color domain. In B.C. Malt

& P. Wolff (Eds.), *Words and the mind: How words capture human experience* (pp. 183-198). New York: Oxford University Press

Roberts, S. H. (2006). Categorizing collections of objects: Linguistic and cognitive factors influencing Welsh and English speakers' judgements. *First Language*, *26*(2), 161–185.

Robinson, C. W., & Sloutsky, V. M. (2007). Linguistic Labels and Categorization in Infancy: Do Labels Facilitate or Hinder? *Infancy*, *11*(3), 233–253.

Rodd, J., Gaskell, G., & Marslen-Wilson, W. (2002). Making Sense of Semantic Ambiguity: Semantic Competition in Lexical Access. *Journal of Memory and Language*, *46*(2), 245–266.

Rosch, Eleanor, & Mervis, C. B. (1975). Family resemblances: Studies in the internal structure of categories. (M. R. DePaul & W. M. Ramsey, Eds.)*Cognitive Psychology*, *7*(4), 573–605.

Ruff, I., Blumstein, S. E., Myers, E. B., & Hutchison, E. (2008). Recruitment of anterior and posterior structures in lexical-semantic processing: an fMRI study comparing implicit and explicit tasks. *Brain and language*,*105*(1),41-9.

Ruhl, C. (1989). *On monosemy: A study in linguistic semantics.* Albany: State University. New York Press.

Russell, B. (1905). On Denoting. *Mind*, *14*(56), 479–493.

Schumacher, R., Wirth, M., Perrig, W. J., Strik, W., & Koenig, T. (2009). ERP correlates of superordinate category activation. *International journal of psychophysiology : official journal of the International Organization of Psychophysiology*, *72*(2), 134–44.

Sebastian, R., Laird, A. R., & Kiran, S. (2011). Meta-analysis of the neural representation of first language and second language. *Applied Psycholinguistics*, *32*(04), 799–819.

Seger, C. A, & Miller, E. K. (2010). Category learning in the brain. *Annual review of neuroscience*, *33*, 203–19.

Simmons, W. K., Hamann, S. B., Harenski, C. L., Hu, X. P., & Barsalou, L. W. (2008). fMRI evidence for word association and situated simulation in conceptual processing. *Journal of physiology, Paris*, *102*(1-3), 106–19.

Smith, M. C., Besner, D., & Miyoshi, H. (1994). New limits to automaticity: Context modulates semantic priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(1), 104–115.

Smith, E. E., & Medin, D. L. (1981). *Categories and Concepts.* Cambridge, Mass: Harvard University Press.

Snowden J., Goulding P., Neary D. (1989) Semantic dementia: a form of circumscribed brain atrophy. *Behavioural Neurology*; 2: 167–82.

B. Stemmer & H. Whitaker (2008.), *Handbook of the neuroscience of language* (pp. 229-236). London: Academic Press

Swinney, D. A. (1991). The Resolution of Interdeterminacy During Language Comprehension: Perspectives on Modularity in Lexical, Structural and Pragmatic Process. In G. Simpson (Ed.) *Understanding Word and Sentence (*Advances in Psychology Series*)*. North-Holland, Amsterdam:

Thompson-Schill, S. L., Aguirre, G. K., D'Esposito, M., & Farah, M. (1999). A neural basis for category and modality specificity of semantic knowledge. *Neuropsychologia* 37, 671–676.

Thompson-Schill, S. L. (2003). Neuroimaging studies of semantic memory: inferring "how" from "where". *Neuropsychologia*, *41*(3), 280–92.

Thierry, G., Wu, Y.J. (2007). Brain potentials reveal unconscious translation during foreign language comprehension, *Proceedings of the National Academy of Science*, USA, 104:12530-

Tulving E. (1972). Episodic and semantic memory. (Tulving E & Donaldson W, eds.) *Organization of memory.* New York: Academic Press. 1972. p. 381-403.

Uğurbil, K., Toth, L., & Kim, D. S. (2003). How accurate is magnetic resonance imaging of brain function? *Trends in neurosciences*, *26*(2), 108–14.

Van Hell, J. G., & Dijkstra, T. (2002). Foreign language knowledge can influence native language performance in exclusively native contexts. *Psychonomic bulletin & review*, *9*(4), 780–9.

Van Heuven, W. J. B., & Dijkstra, T. (2010). Language comprehension in the bilingual brain: fMRI and ERP support for psycholinguistic models. *Brain research reviews*, *64*(1), 104–22.

Veltman, D., Hutton, C., Ashburner, J., & Henson, R. (2001). *SPM99 Manual* - May 2001, (May), 1–86.

Vigneau, M., Jobard, G., Mazoyer, B., & Tzourio-Mazoyer, N. (2005). Word and non-word reading: what role for the Visual Word Form Area? *NeuroImage*, *27*(3), 694–705.

Vygotsky, L. (1962). *Thought and language*. (E. Haufmann & G. Vakar, Eds.). Cambridge, MA: The MIT press.

Wang, X., & Forster, K. I. (2010). Masked translation priming with semantic categorization: Testing the Sense Model. *Bilingualism: Language and Cognition*, *13*(03), 327–340.

Warrington E.K., Shallice T. (1984). Category specific semantic impairments. *Brain* 107, 829-854.

Wei, L. (2006). The Multilingual Mental Lexicon and Lemma Transfer in Third Language Learning" in *International Journal of Multilingualism* 3/2, 88-104 (2006).

Wernicke, C. (1874): *Der aphasische Symptomenkomplex. Eine psychologische Studie auf anatomischer Basis*. Breslau: M. Cohn & Weigert

Whitney, C., Jefferies, E., & Kircher, T. (2011). Heterogeneity of the left temporal lobe in semantic representation and control: priming multiple versus single meanings of ambiguous words. *Cerebral cortex (New York, N.Y. : 1991)*, *21*(4), 831–44.

Whorf, B. L. (1956). *Language, Thought, and Reality: Selected Writings of Benjamin Lee Whorf*. (J. B. Carroll, Ed.) *Technology* (Vol. 8, p. 290). MIT Press.

Willems, R. M., Ozyürek, A., & Hagoort, P. (2008). Seeing and hearing meaning: ERP and fMRI evidence of word versus picture integration into a sentence context. *Journal of cognitive neuroscience*, *20*(7), 1235–49.

Winhuisen, L., Thiel, A., Schumacher, B., Kessler, J., Rudolf, J., Haupt, W. F., & Heiss, W. D. (2007). The right inferior frontal gyrus and poststroke aphasia: a follow-up investigation. *Stroke; a journal of cerebral circulation*, *38*(4), 1286–92.

Wittgenstein, L. (1953). *Philosophical Investigations*. (G. E. M. Anscombe, Ed.) *The American Journal Of Bioethics Ajob* (Vol. 34, pp. 48–52). Blackwell.

Wolff, P., & Ventura, T. (2009). When Russians learn English: How the semantics of causation may change. *Bilingualism: Language and Cognition*, *12*(02), 153.

Wong, C., J., H., & Gallate, J. (2012). Evidence for a Social Function of the Anterior Temporal Lobes: Low Frequency rTMS Reduces Implicit Gender Stereotypes. *Social Neuroscience*. 7(1), 90-104.

Yokoyama, S., Okamoto, H., Miyamoto, T., Yoshimoto, K., Kim, J., Iwata, K., Jeong, H., (2006). Cortical activation in the processing of passive sentences in L1 and L2: an fMRI study. *NeuroImage*, *30*(2), 570–9.

Zempleni, M.Z., Renken, R., Hoeks, J. C. J., Hoogduin, J. M., & Stowe, L. A. (2007). Semantic ambiguity processing in sentence context: Evidence from event-related fMRI. *NeuroImage*, *34*(3), 1270–9.

Appendices

Appendix 1

Stimuli relatedness questionnaire

<u>Semantic relatedness form</u>

In the following sentences, you will be presented with two word pairs- Each time you will be asked to rate the relation between the <u>meanings</u> of the two word pairs by marking one of the boxes-

INSTRUCTIONS

Are the meanings of the 2 words in Ⓑ related in a way that is similar to the way in which the meanings of the 2 words in Ⓐ are related? Put an X in the box that corresponds to your judgment (Some of these may seem rather off the wall- Don't worry, just make your best judgment and don't think too long about any of them)-

Example-

Ⓐ ***Lion - Cat***			Ⓑ ***Wolf - Dog***	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*
				X

Ⓐ ***Egg – Shell***			Ⓑ ***Brain – Skull***	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*
				X

Ⓐ ***Stapler - Paper***			Ⓑ ***Shoehorn - Car***	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*
				X

Ⓐ Beak – Pickaxe			Ⓑ Tail – Whip	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Earnings- Winnings			Ⓑ Purchase – Prize	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Paper – Pen			Ⓑ Key – Lock	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Treetop – Cup			Ⓑ Root – Tripod	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Needle – Minute Hand			Ⓑ Wheel – Hoop	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Wood - Timber			Ⓑ Holiday – Mushroom	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Meadow - The Country			**Ⓑ Forest– Mountain**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Finger - Toe			**Ⓑ Elbow - Knee**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Robe – Smock			**Ⓑ Overalls – Apron**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Note (UK) / Bill (US) – Ticket			**Ⓑ Token – Voucher**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Flour - Soap			**Ⓑ Ball – Watermelon**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Clock – Watch			**Ⓑ Gauge – Metronome**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Morning - Tomorrow**			Ⓑ **Night – Yesterday**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Beach - Sand**			Ⓑ **Banner – Engine**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Focus - Spotlight**			Ⓑ **Beam – Headlight**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Rubber - Elastic Band**			Ⓑ **Plastic – Zip Tie**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Necklace – Dog Collar**			Ⓑ **Mask - Muzzle**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Bicycle - Motorcycle**			Ⓑ **Radio – Video**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Flame – Llama**			Ⓑ **Fire – Goat**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Musical Note - Grade**			Ⓑ **Whole number - Percentage**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Track - Clue**			Ⓑ **Pool – Drop**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Thermometer - Ruler**			Ⓑ **Bone – Shell**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Tweezers - Clothespin**			Ⓑ **Scissors – Clamp**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Rat - Lemon**			Ⓑ **Kangaroo – Orange**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **File – Lime**			Ⓑ **Hammer - Lemon**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Tail – Glue**			Ⓑ **Head - Blutack**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Card – Chrome**			Ⓑ **Discount Coupon- Steel**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Hull (of boat) - Helmet -**			Ⓑ **Breadbox – Skip (UK) / Dumpster (US)**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Book - Mug**			Ⓑ **Magazine – Glass**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Rock - Stone**			Ⓑ **Biscuit – Cake**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Paw - Table Leg			**Ⓑ Torso – Pillar**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Gang – Sash			**Ⓑ Army – Ribbon**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Deck – Tyre			**Ⓑ Diving board – Sole (of foot)**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Truck - Sardine			**Ⓑ Teacher – Pillow**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Basement - Bass Guitars			**Ⓑ Attic – Flute**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Cape - Layer			**Ⓑ Hood – Cover**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Mattress - Cable			Ⓑ Train – Clarinet	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Can (for food) – Boat			Ⓑ Bottle – Airplane	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Scarf - Glove			Ⓑ Parrot – Cow	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Candle – Sail			Ⓑ Light Bulb - Propeller	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Gear - March -			Ⓑ Skeleton – Chassis	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Desk - Trumpet			Ⓑ Lamp – Salmon	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Ladies - Queens			Ⓑ Pawns – Chess	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Number Plate – Badge			Ⓑ Doorplate - Name tag	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Rope– String			Ⓑ Tube - Hose	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Fine - Ticket			Ⓑ Admission - Entry	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Farm - Cattle			Ⓑ Dance – Reactor	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Fine - Ticket			Ⓑ Pre-booking – Boarding Pass	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Cardboard - Paper**			Ⓑ **Circuit – Mill**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Sheet Metal - Bottle cap**			Ⓑ **Plate Glass– Shot glass**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Championship - Trophy**			Ⓑ **Academy Award – Oscar**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Snow - Ice**			Ⓑ **Castle – Asparagus**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Puppy – Cub**			Ⓑ **Dog - Bear**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Mesh – Chain mail**			Ⓑ **Canvas - Awning**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Balm - Painkiller**			Ⓑ **Monkey – Shovel**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Lenses - Glasses**			Ⓑ **Bracelet – Bangle**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Fishing - Catch**			Ⓑ **Hunting – Game**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Boot - Wineskin**			Ⓑ **Ring – Napkin Holder**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Car - Bus**			Ⓑ **Lever – Button**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Locust - Lobster**			Ⓑ **Cockroach – Shrimp**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Population - Village			Ⓑ Citizenship – nation	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Step - Access			Ⓑ Door – Entry	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Seat - Armchair			Ⓑ Mattress – Futon	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Roof – Ceiling			Ⓑ Drywall - Stucco	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Pigeon – Dove			Ⓑ Leopard - Panther	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Mud - Clay			Ⓑ Slush – Snow	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Cruise - Steamship**			Ⓑ **Flight – Plane**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Cane – Reed**			Ⓑ **Hedge - Bush**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Tin (UK)/ Can (US) – Jar**			Ⓑ **Glass - Mug**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Bomb – Pump**			Ⓑ **Grenade - Tap (UK) / Faucet (US)**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Handle – Mango**			Ⓑ **Doorknob - Pineapple**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ **Cardinal – Bruise**			Ⓑ **Pope - Sore**	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Malta – Doll			Ⓑ Ankle - Teddy bear	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Field – Golf Course			Ⓑ Building - Stadium	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Fire - Cocoon			Ⓑ Smoke – Butterfly	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Clover – Clubs			Ⓑ Star - Asterisk	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Oil Painting - Oil			Ⓑ Tapestry – Threads	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Coil – Golf Course			Ⓑ Spring - Slinky	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Phone Booth (US)/ Phone Box (UK) - Cockpit			Ⓑ House - Kitchen	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Lid – Book cover			Ⓑ Stand - Podium	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Kilt - Skirt			Ⓑ Pole – Rod	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Stairs – Ladder			Ⓑ Elevator - Chairlift	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Wrist – Doll			Ⓑ Ankle - Teddy Bear	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Plant – Storey			Ⓑ Mushroom - Door	
1	2	3	4	5
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Bank – Bench			Ⓑ Post office - Chair	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can’t tell*	*Rather similar*	*Very similar*

Ⓐ Chant – Edge			Ⓑ Jazz - Corner	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can’t tell*	*Rather similar*	*Very similar*

Ⓐ Calculation - Bill			Ⓑ Composition – Score	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can’t tell*	*Rather similar*	*Very similar*

Ⓐ Coffee - Tea			Ⓑ Soup – Screw	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can’t tell*	*Rather similar*	*Very similar*

Ⓐ Carp – Marquee			Ⓑ Mackerel - Umbrella	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can’t tell*	*Rather similar*	*Very similar*

Ⓐ Cousin – Bonus			Ⓑ Brother - Gift	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can’t tell*	*Rather similar*	*Very similar*

Ⓐ Fishbone - Thorns			Ⓑ Rib – Hook	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Neck - Collar			Ⓑ Wrist – Sleeve	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Comet - Kite			Ⓑ Rain – Sprinkler	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Court – A Cut			Ⓑ Council - Dent	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Ⓐ Sunflower Seed – Smoking Pipe -			Ⓑ Almond - Cigarette	
1	*2*	*3*	*4*	*5*
No similarities at all	*Maybe some connection but not really similar*	*I can't tell*	*Rather similar*	*Very similar*

Appendix 2

Language information questionnaires for category membership study

Catalan version

QUESTIONARI

Gràcies per participar en aquest estudi- Si us plau, completau el següent questionari- L´informació recollida serà guardada de manera totalment anònima-

Edat____________ Sexe__H/D___

Quines llengües parles?

☐ **Català**

A quina edat (aprox-) vares aprendre aquesta llengua? ________________

Aproximadament, quin percentaje del teu temps parles en català, en relació amb altres llengües?

A- 100% ☐ B- 75% ☐ C- 50% ☐ D- 25% ☐ E- 0% ☐

☐ **Espanyol**

A quina edat (aprox-) vares aprendre aquesta llengua? ________________

Aproximadament, quin percentaje del teu temps parles en espanyol, en relació amb altres llengües?

A- 100% ☐ B- 75% ☐ C- 50% ☐ D- 25% ☐ E- 0% ☐

☐ **Altra llengua, si us plau, especificau** ______________________

A quina edat (aprox-) vares aprendre aquesta llengua? ________________

Aproximadament, quin percentaje del teu temps parles en català, en relació amb altres llengües?

A- 100% ☐ B- 75% ☐ C- 50% ☐ D- 25% ☐ E- 0% ☐

Spanish version

CUESTIONARIO PARA PARTICIPANTES

Gracias por participar en este estudio- Por favor, completa el siguiente cuestionario- La información recogida aqui sera guardada de forma totalmente anónima-

Edad______________ Sexo__H/M____

¿Qué idiomas hablas?

☐ **Español**
Edad a la que empezaste a hablar español ________________

Aproximadamente, ¿qué porcentaje de tu tiempo hablas español, en relación a otros idiomas?-

A- 100% ☐ B- 75% ☐ C- 50% ☐ D- 25% ☐ E- 0% ☐

☐ **Otra lengua –** Por favor, especifica aquí__________________________
Edad a la que empezaste a hablar esta lengua____________________

Aproximadamente, ¿qué porcentaje de tu tiempo hablas español, en relación a otros idiomas?-

A- 100% ☐ B- 75% ☐ C- 50% ☐ D- 25% ☐ E- 0% ☐

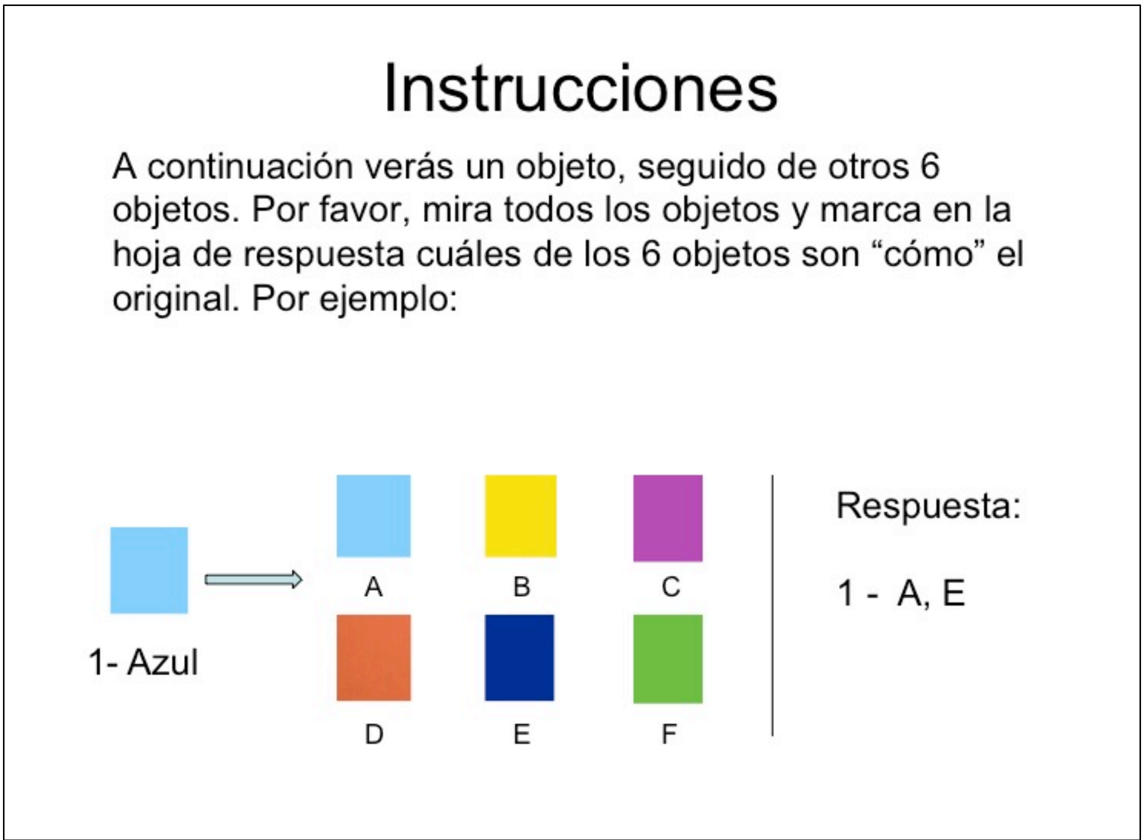
☐ **Otra lengua –** Por favor, especifica aquí__________________________
Edad a la que empezaste a hablar esta lengua____________________

Aproximadamente, ¿qué porcentaje de tu tiempo hablas español, en relación a otros idiomas?-

A- 100% ☐ B- 75% ☐ C- 50% ☐ D- 25% ☐ E- 0% ☐

Appendix 3

Stimuli used in the category membership study (label condition is depicted- Non-label condition was identical with the omission of labels)



You will now see an object, followed by 6 other objects- Please, look at all objects and mark in your response sheet which of the 6 objects are like the original- For example-

PRACTICA

(PRACTICE)

100 -
TELEFONO

(TELEPHONE)


A


B


C


D


E


F


A


B


C


D


E


F

RESPUESTAS CORRECTAS: B, C, D

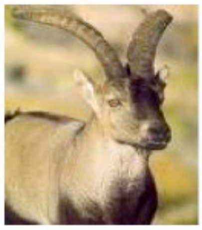
(CORRECT RESPONSES- B, C, D)

200 - PAJARO

(BIRD)

A

B



C

D

E

F

A

B

C

D

E

F

RESPUESTAS CORRECTAS: E

(CORRECT RESPONSES- E)

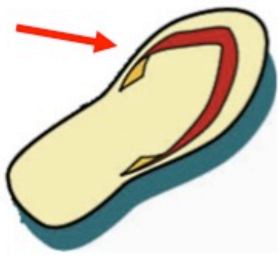
FIN DE LA PRACTICA

¿ALGUNA PREGUNTA?

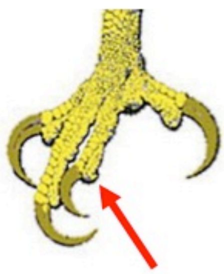
(END OF PRACTICE- ANY QUESTIONS?)

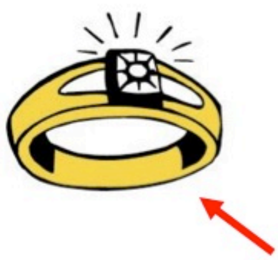
1 - DEDO

(FINGER)



A B C





D E F

2 - ARBOL

(TREE)

A

B

C

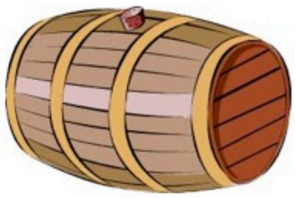
D

E

F

3 - BOTA

(BOOT)



A

B

C

D

E

F

4 - COFRE

(CHEST)

A

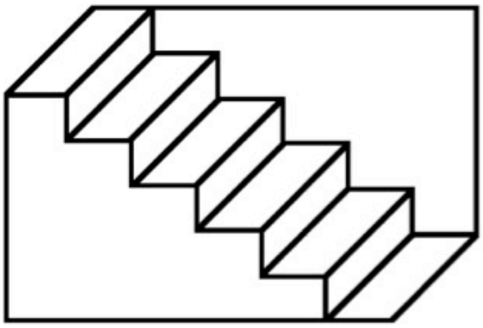
B

C

D

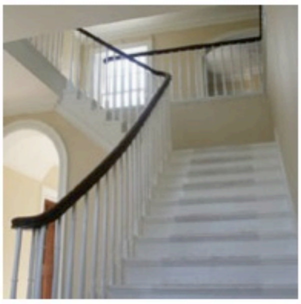
E

F



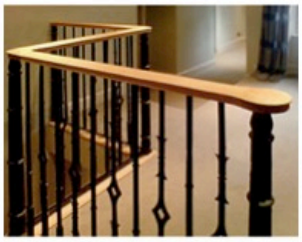
5 - ESCALERA

(STAIRS)



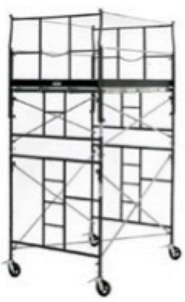
A

B



C

D



E

F

6 - LLAVE

(KEY)

A

B

C

D

E

F

7 - PINTURA

(PAINT)

A

B

C

D

E

F

8 - LETRAS

(LETTERS)

A

B

C

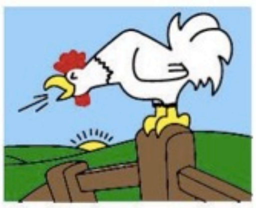
D

E

F

9 - RELOJ

(CLOCK)

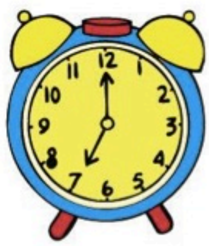


A

B

C

D



E

F

10 - CAMPANA

(BELL)

A

B

C

D

E

F

11 - PLANTA

(PLANT)

A

B

C

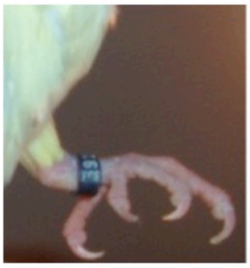
D

E

F

12 - UÑA

(NAIL)



A

B

C

D

E

F

13 - CAJA

(BOX)

A

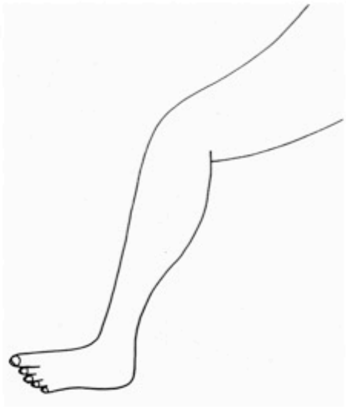
B

C

D

E

F

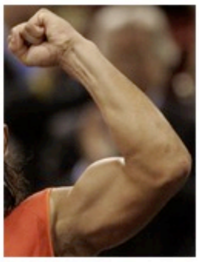


14 - PIERNA

(LEG)

A

B



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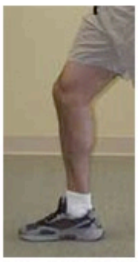


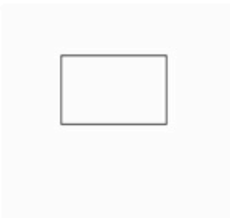
D

E

F

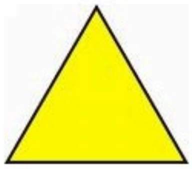
15 - CUADRO

(PAINTING)



A

B



C

D

E

F

16 - GAFAS

(GLASSES)

A

B

C

D

E

F

17 - CINTA

(RIBBON)

A

B

C

D

E

F

18 - ABRIGO

(COAT)

A

B

C

D

E

F

19 - BANCO

(BANK)

A

B

C

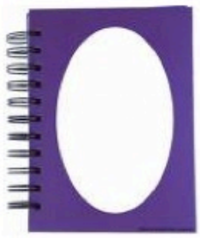
D

E

F

20 - BOLIGRAFO

(PEN)

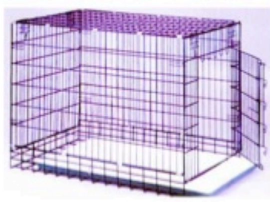


A

B

C

D



E

F

21 -ARCO

(ARCH)

A

B

C

C

D

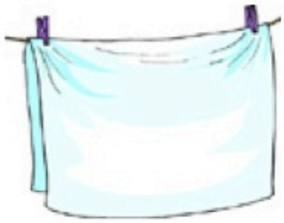
E

22 - HOJA

(SHEET)

A

B



C

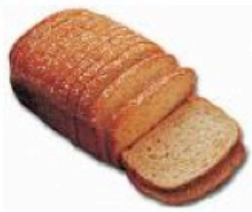
D

E

F

23 - PLATO

(DISH)



A

B

C

D

E

F

24 - TE

(TEA)

A

B

C

D

E

F

Appendix 4

Stimuli used in the priming and fMRI studies

Classical categories

Finger-Toe -	Elbow-Knee
Robe-Smock -	Overalls-Apron
Note-Ticket -	Token-Voucher
Clock-Watch -	Gauge-Metronome
Necklace-Dog Collar -	Mask-muzzle
Rock-Stone -	Biscuit-Cake
Number plate-Badge -	Doorplate-Nametag
Rope-String -	Tube-Hose
Puppy-Cub -	Dog-Bear
Mesh-Chainmail -	Canvas-Awning
Roof-Ceiling -	Drywall-Stucco
Pigeon-Dove -	Leopard-Panther
Cane-Reed -	Hedge-Bush
Tin-Jar -	Glass-Mug
Field- Golf Course -	Building-Stadium
Stairs-Ladder -	Elevator-Chairlift
Clover-Clubs -	Star-Asterisk

Homonyms

Tail – Glue -	Head - Bluetac
Can (food) –Boat-	Bottle – Airplane
Candle – Sail -	Light bulb - Propeller
Wrist – Doll -	Ankle - Teddy bear
Bank – Bench-	Post office - Chair
Cousin – Bonus	Brother - Gift
Sunflower seed- Smoking pipe-	Almond - Cigarette
File – Lime -	Hammer - Lemon
Flame – Llama -	Fire – Goat
Gang – Sash -	Army – Ribbon
Bomb – Pump-	Grenade - Tap
Handle – Mango-	Doorknob - Pineapple
Cardinal – Bruise-	Pope - Sore

Radial taxonomic

Beak - Pickaxe - Tail - Whip
Earnings- Winnings - Purchase - Prize
Paw - Table leg - Torso - Pillar
Basement - Bass guitars Attic - Flute
Cape - Layer - Hood - Cover
Ladies - Queens - Pawns - Chess
Locust - Lobster - Cockroach - Shrimp
Seat - Armchair - Mattress - Futon
Mud - Clay - Slush - Snow
Lid – Book cover - Stand - Podium

Radial thematic

Meadow - The country- Forest– Mountain
Morning - Tomorrow- Night – Yesterday
Focus - Spotlight - Beam – Headlight
Rubber - Elastic Band- Plastic – Zip tie
Fine - Ticket - Admission – Entry
Fine - Ticket - Pre booking – Boarding pass
Sheet metal - Bottle cap- Plate glass– shot glass
Championship - Trophy - Academy award – Oscar
Lenses - Glasses - Bracelet – Bangle
Fishing - Catch - Hunting – Game
Population - Village - Citizenship – nation
Step - Access - Door – Entry
Cruise - Steamship - Flight – Plane
Oil Painting - Oil - Tapestry – Threads
Calculation - Bill - Composition – Score
Neck - Collar - Wrist – Sleeve

Unrelated Controls

Paper – Pen- - Key – Lock
Wood - Timber - Holiday – Mushroom
Flour - Soap - Ball – Watermelon
Beach - Sand - Banner – Engine
Bicycle - Motorcycle - Radio – Video
Thermometer - Ruler- Bone – Shell
Rat - Lemon - Kangaroo – Orange
Book - Mug - Magazine – Glass
Truck - Sardine - Teacher – Pillow
Mattress - Cable - Train – Clarinet
Scarf - Glove - Parrot – Cow
Desk - Trumpet - Lamp – Salmon
Farm - Cattle - Dance – Reactor

Cardboard - Paper	-	Circuit – Mill
Snow - Ice	-	Castle – Asparagus
Balm - Painkiller	-	Monkey – Shovel
Car - Bus	-	Lever – Button
Fire - Cocoon	-	Smoke – Butterfly
Kilt - Skirt	-	Pole – Rod
Coffee - Tea	-	Soup – Screw
Hat - Stone	-	Cap – Brick

Non-Words (in the fMRI study, only the non-words shown in this page were used)

hayed	spudged	bepisked	fambeds
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jemptuous	smenched	implisque	bloudesome
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plompous	cleathson	skirredy	squark
swinched	tealorked	wernsome	dwimmands
cloothed	screelement	unplourge	vadgelic
crallants	tupester	glowfube	thirledy
bochets	creedant	earnesher	imporlet
splifters	whangest	drealed	pladgement
boops	hilkee	streezee	spefolation
bromery	swondous	sclammed	snurchety
bloar	tudestry	feks	kudgedel
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slurchers	murpedity	parled	skollstery
dwobseley	prasking	menledy	yinedness
groots	joogelery	sleanster	nerbsome
porsenst	zasket	yile	strudgeful
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curfed	sprupendous	troudsent	hoshedee
whilchend	engedian	cracer	smorgeling
glopedic	drookard	cleaguent	lortsome
nylestic	drekston	giboured	fliveless
prushed	scunestic	faubous	glouthedant
strilched	pakent	exculge	yitchic
jimmborous	blurkomatic	clute	flandstry
groocher	thobement	swurpant	fleechement
glokens	impounance	frumbee	goansic
foshery	shealamp	skolkement	streepsless
skatcher	woleston	crompels	straunter
nuse	skavesty	fraspseed	splungdent
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nawksome
bowhools
snuses
furching
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glunnedment
untersed
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neaned
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treapish
crubster
gleathee
jomes
tourned
crastpliff
duseglute
phintz
shrad
yimmed
swaskspleek
cronths
chitchen
slebscoke
whimes
smork

slanktous
dralkwack
blornet
preague
phlothed
shuned
prowne
fithbrene
trandpot
potcloin
dwizzed
sleece
roosh
narved
spensed
scoatcrance
maged
shratoid
mointsprat
hountdroove
craped
scroudwince
blartburr
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braldbluzz
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chunecore
splentreen
gluke
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skencaves
spourglard
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sprooths
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clardfong
scroud
snoves
mirchent
snurfster
unsteaves
twarked
pligued
flincequeale
stroobs
stilchet
fenthom
scretchless
stoonster
twanket
drobest
phlieger
glatson
clarmst

queaker
wifevail
hounged
weamay
scrowled
splanks
gombous
bluresity
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clorksome
cibedely
fliskset
splanned
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Appendix 5

Language background questionnaire used in the priming and fMRI studies

LANGUAGE INFORMATION QUESTIONNAIRE

Name-____________________________________ Birth Date- __________

I wish to participate in this study ( ) YES ( ) NO

1- Which languages do you speak? (Please tick all that apply)

☐ English

I began speaking English at age-___________________
Please state approximately what percentage of the time you speak English on a daily basis-

A- 100% ☐ B- 75% ☐ C- 50% ☐ D- 25% ☐ E- 0% ☐

Please state approximately what percentage of the time English is currently spoken in the home-

A- 100% ☐ B- 75% ☐ C- 50% ☐ D- 25% ☐ E- 0% ☐

☐ Other language(s) – please specify-______________________________

I began speaking this language at age-______________
Please state approximately what percentage of the time you speak this language on a daily basis-

A- 100% ☐ B- 75% ☐ C- 50% ☐ D- 25% ☐ E- 0% ☐

Please state approximately what percentage of the time this language is currently spoken in the home-

A- 100% ☐ B- 75% ☐ C- 50% ☐ D- 25% ☐ E- 0% ☐

2- On a scale of 1 to 5 (5 highest), how well do you feel you **speak** English?

1	2	3	4	5
Only know some words and expressions		Can carry out basic conversations		Can carry out extended conversations

Comments- ____

3- On a scale of 1 to 5 (5 highest), how well do you feel you **understand** English?

1	2	3	4	5
Only know some words and expressions		Can understand basic		Can understand all or most

		conversations		conversations

Comments- ____

B- On a scale of 1 to 5 (5 highest), how well do you feel you **<u>read</u>** English?

1	2	3	4	5
I can only read a little		I can read most things reasonably well		I can read almost anything very well

Comments- ____

B- On a scale of 1 to 5 (5 highest), how well do you feel you **<u>write</u>** English?

1	2	3	4	5
I only know how to write a few words and expressions		I can only write simple things		I can write practically anything I want

Comments- ____

Date and signature_____________________________

Thank you for your participation-

Appendix 6

Stimuli used in the ERP priming study

Classical categories

gut : tripe
wood : lumber
fighter : wrestler
fat : grease
peacock : turkey
finger : toe
cable : cord
race : breed
jar : tin
note : ticket
roof : ceiling
rope : string
watch : clock
flesh : meat
ladder : stairs
weed : grass
stone : rock
plank : board
necklace : collar
history : story

Radial categories

locust : lobster
fine : ticket
blackboard : slate
cape : layer
rubber : eraser
lenses : glasses
fountain : source
queue : line
leaf : sheet
canal : channel
comet : kite
grain : spot
mud : clay
mark : brand
earnings : winnings
focus : spotlight
front : forehead
chair leg : paw
letter : card
morning : tomorrow

Homonyms

mermaid : siren
cardinal : bruise
corporal : cape
thorn : fishbone
chant : edge
fragrance : colony
carp : marquee
candle : sail
flame : llama
can : boat
wrist : doll
mango : handle
battery : drumset
gang : sash
bomb : pump
tail : glue
cat : car jack
file : lime
bank : bench
court : cut

Unrelated Controls

thermometer : brick
clarinet : pen
mushroom : timber
banner : key
screw : bone
butterfly : smoke
bicycle : sand
shaft : clover
rat : coffee
ruler : hat
blanket : magazine
flour : video
lemon : engine
soap : holiday
pole : ball
cow : tea
truck : radio
skirt : fire
soup : book
cap : beach

Related Controls

dog : wolf
scarf : gloves
parrot : duck
desk : counter
college : university
television : radio
mug : cup
aircraft : helicopter
pound : pence
pool : pond
hill : mountain
aunt : uncle
rat : hamster
hut : shack
whale : dolphin
flat : apartment
stool : chair
mist : fog
lane : path
tree : bush