Learning and Memory in the Bilingual Mind and Brain

Article · March 2019
DOI: 10.1002/9781119387725.ch19

5 authors, including:

Allison M. Wilck
University at Albany, The State University of New York
8 PUBLICATIONS 1 CITATION
See Profile

Jeanette Altarriba
University at Albany, The State University of New York
127 PUBLICATIONS 3,524 CITATIONS
See Profile

Roberto Ramírez Heredia
Texas A&M International University
44 PUBLICATIONS 483 CITATIONS
See Profile

Michel Paradis
McGill University
108 PUBLICATIONS 2,279 CITATIONS
See Profile

Some of the authors of this publication are also working on these related projects:

- Survival Memory and Face Recognition View project
- Stereotypes and Eye-tracking View project
Thank you for using the University at Albany’s Interlibrary Loan Service

NOTICE WARNING CONCERNING COPYRIGHT RESTRICTIONS

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted material. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specific conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement. This institution reserves the right to refuse a copying order if, in its judgment, fulfillment of the order would involve violation of copyright law.

Questions?
Call 442-3613 from 10:00 ~ 4:30 (weekdays)
or
Send email to libill@albany.edu
19 Learning and Memory in the Bilingual Mind and Brain

ALLISON M. WILCK, JEANETTE ALTARRIBA, ROBERTO R. HEREDIA, AND JOHN W. SCHWIETER

1. Introduction

Bilingual speakers operate independently in their first (L1) or second language (L2), or interdependently in which both languages interact simultaneously as in language mixing or code switching. How do bilingual (or multilingual) speakers organize their linguistic systems in the brain? Are the languages organized in the same or separate brain regions? This chapter explores various aspects and assumptions of models of bilingual language processing and organization. A brief overview of theoretical language models is provided to include a discussion of the distinction between compound and coordinate bilingualism, as well as models of connectionism, hierarchical structures, and a recently proposed model of language acquisition. The underlying assumptions of these theories and models will be assessed with a focus on interlanguage processing and organization.

One purpose of this chapter is to underscore the importance of bilingual research to aid in the refinement of existing theoretical constructs that distinguish between conceptual meaning and lexical representations, for example, and to provide further evidence for structural assumptions of language processing models (Altarriba and Soltano 1996). Bilingual research, in addition to helping us understand an individual with knowledge of two or more languages, provides yet another opportunity to assess, correct, and expand existing models and theories of language processing. Bilingualism provides a unique perspective for understanding how words and sentences are learned, encoded, stored, and retrieved from memory.

Additionally, how meaning is derived from language, both within and between languages, must be considered from several perspectives to include the nature of the words, how and when the language has been acquired by the individual, and the consistency of processing across languages in a given context. Overall, the bilingual and L2 literature
supports the view that there are various layers of information extracted from words (e.g. physical features, conceptual meaning) that become interlinked with the acquisition of new languages (e.g. Velan and Frost 2007, 2011; Wong et al. 2011). Within the bilingual mind, the research largely supports models that incorporate a mixed linguistic representation: some aspects of language share a common store while others are separate with language specificity. By studying language processing in bilinguals and multilinguals, a better understanding of how information is generally integrated into human memory can be obtained.

2. Overview of Theories and Models of Bilingual/ Multilingual Memory

Human memory is a rich and complex system that has been researched in a variety of capacities for decades from working memory (e.g. Baddeley 2003; Baddeley and Hitch 1974) to long-term memory (Lynch 2004). However, there is not an undisputed understanding of how information is processed, stored, and retrieved in memory (see Baddeley et al. 2015), and there have been numerous models proposed on how language is processed in memory (see French and Jacquet 2004; Kroll and Tokowicz 2005). Research findings from bilinguals and multilinguals have led to the development of models that attempt to account for how individuals with knowledge of more than one language store and extract information within and across languages. In this section, we provide a brief overview of a number of models addressing bilingual and multilingual language processing, beginning with the fundamental debate between memory store organizations and concluding with more recent and well-defined models (for additional discussions on models of bilingual language processing, see Heredia and Cieślicka 2018).

2.1. Language Memory Stores

The seminal research into the uniqueness of bilingual language processing and representation comes from Ervin and Osgood (1954). The distinction between compound and coordinate bilingualism provides the basis for today’s models. Compound bilinguals are those who became proficient in an L2 by relating and matching the to-be-learned concepts back to those in their L1. Connecting the new language concepts to those already in memory, it was proposed that there would be an overlap of representations such that all linguistic information would be stored in one location within the brain. On the other hand, coordinate bilinguals are those who acquired a new language in a context that is distinct from any previous language knowledge. For example, if an individual learned English in the home through immersion, but was explicitly taught French in a classroom, then these two languages would come to have separate representations. Under these conditions, English words and their French translations would not be interpreted as having identical meanings and associations. Therefore, word translations would not be processed and stored equivalently, and words from each language would have their own cognitive store.
An important underlying distinction between these types of bilinguals is the implication that the individual must encode information in a context-specific manner. In other words, for each word bilinguals encounter, they must make note of the learning conditions, so as to later be able to retrieve the meaning of the word in accordance with its appropriate language. Although acquisition may be affected by learning context (Segalowitz and Freed 2004), this theory does not allow for the possibility of alterations as a product of experience with the languages after the initial learning or from the nature of the linguistic codes themselves (see Kopeliovich 2006; cross-linguistic word features will be discussed further in Section 4 below).

In the present-day literature, it is a rarity to encounter the compound versus coordinate bilingualism distinction. Although Ervin and Osgood (1954) generated their understanding based on how language was acquired, the current debate tends to focus on how linguistic information is stored and processed in memory. Updating and expanding their seminal proposal, the more recent psycholinguistic literature investigates if linguistic information in individuals with knowledge of more than one language is stored within a single mental lexicon, or among multiple, separate stores. If multiple stores indeed exist, the degree of interaction and interconnectivity between them remains a topic of discussion.

Theorists supporting a single, interdependent linguistic store largely argue that the concepts represented by words are stored as language-free abstract meanings (see Heredia and Cieslicka 2018, for a review of the literature supporting the shared memory hypothesis). These concepts are then ‘tagged’ with labels corresponding to the word or phrase associated with each known language. For example, the conceptual representation for the place one lives will be tagged in an English-Spanish bilingual with both house and casa. Therefore, when this concept becomes activated, both labels would be accessible for use, and the bilingual can attend to the tag that is most applicable for the current conversation. This shared memory hypothesis predicts that the underlying concepts of information learned in one language (e.g. $3 + 4 = 7$, or seven in English) will be able to be retrieved in one’s L2 (siete in Spanish) without the need to relearn the notion in each tongue. Tasks that emphasize a conceptual focus and accentuate attention towards the meaning of words, such as recall and recognition tests of semantic meaning and relational processing, often garner support for an interdependence model of bilingual and multilingual language processing (see Heredia and Cieslicka 2018).

In contrast to a single memory store is the separate or independence memory hypothesis (Kolers 1963). This stance posits that linguistic information is processed, stored, and retrieved unimodally, with each learned language having its own distinct memory store. The separation of lexicons is proposed to emphasize the quantitative differences of words and concepts learned between languages. These differences can be derived by comparing linguistic aspects such as word morphology, phonology, orthography, or learnability. Furthermore, interactions between stores only occur through translation processes, and therefore, information obtained in one language store is often not available to another. Support for this hypothesis comes from experiments that utilize tasks that are sensitive to data-driven or perceptually-based factors (e.g. lexical decision tasks). Additional evidence for this hypothesis comes from tasks involving code switching (i.e. alternating between a bilingual’s two languages within a single sentence). For example, intermixed
English-Spanish sentences (e.g. *dame una hamburguesa sin LETTUCE por favor*) take English-Spanish bilinguals longer to process than do the monolingual equivalents (*give me a hamburger without LETTUCE please*; Heredia and Altarriba 2001). When assessed using the separate language stores hypothesis, these results can be explained with one language store being fully searched for each word’s meaning before searching another, with search typically beginning in the speaker’s primary language or the language that is currently more activated (e.g. Dijkstra and Van Heuven 2002; Soares and Grosjean 1984).

To combine the concepts of both the interdependent and independent memory store hypotheses, models with separate but interconnected bilingual memory stores have been proposed. One of the more well-known models, the bilingual dual-coding theory (Paivio and Desrochers 1980), predicts that each language of a bilingual speaker has a separate store for its verbal code that can function independently. Within each verbal code, there is information pertaining to the specific language’s word labels and syntax. Although stored separately, these verbal systems are linked through translation equivalents. The stronger the labels are between languages for a given concept map onto each other, the stronger and more accessible the links are. For example, the translation equivalents of *cheese* in English and *fromage* in French produce a stronger association, as compared to the related concepts of *cheese* and *pain* (bread in French).

Importantly, the bilingual dual-coding theory can also account for many language type effects with the inclusion of a third, language-free image store that is linked to the verbal stores. Language type effects refer to differences in attention, reaction time, or other responses because of manipulations in word type (e.g. abstract, concrete, emotion [words describing an affective state, such as *joyful*], or emotion-laden [words that evoke emotion, such as *funeral*]), or language presentation. There is ample evidence for a bilingual concreteness effect in which tangible objects (e.g. *chair, tiger, bottle*) are better recalled from memory than abstract words (e.g. *dream, love, death*; Altarriba and Bauer 2004; de Groot 1992; Farley et al. 2012). It is important to note that tangible objects or nouns score high in imagery accessibility and often have a single translation between languages, while abstract words are lower in imageability and often map onto multiple translations (see Altarriba 2003). Therefore, concrete nouns can activate meaning from all three stores (L1, L2, and imagery) of the bilingual dual-code model, while abstract and other word types are often limited to only the verbal encodings.

The search for a structural and functional understanding of how language is processed in memory continues to be a predominant area of research in the fields of neuroscience and psycholinguistics. Whether there exists a single mental lexicon that encompasses all linguistic information, separate stores for each language, or some combination of these is an ongoing discussion. However, many models have been proposed that incorporate the acquisition and recall of various lexical properties that can be organized according to their underlying theoretical assumptions.

### 2.2. Connectionist Models

Connectionist models of linguistic acquisition come from the field of cognitive psychology. These models function to bridge linguistic knowledge and organization with the mechanisms that operate them. In general, connectionism has been used to describe
behaviours that can be attributed to neuronal connections or other basic units. When describing language acquisition, it is common to refer to these basic conceptual units as nodes that interact through weighted connections (see Figure 1). Connections are formed when associations between nodes are created, and their connective strength is increased as learning occurs. This learning can arise from interactions with the environment that allow for broad categories and rules to develop to link concepts together. For example, when learning the meaning of an unfamiliar word, the features of the individual letters must first be interpreted and then connected to form a meaningful word unit. Once the unit has been established as a word, meaning can be applied to it and this meaning can be grouped together with concepts already established in memory.

One of the most cited connectionist word recognition models is the bilingual interactive activation model (BIA; Dijkstra and Van Heuven 2002), currently modified to the BIA+ model (Chauncey et al. 2008; Grainger et al. 2010). This network model posits that information about the physical appearance of word features initiates the activation of letter recognition, followed by word recognition and semantic comprehension. These various lexical levels interact to identify a meaning for the presented words, with the underlying assumption that activation is not language specific. Information across all of an individual’s known languages is integrated in a single lexicon, with a given word being recognized as belonging to a specific language. When presented within a language task, the information from both languages will become activated simultaneously until enough evidence is gathered to determine the language most appropriate to continue using for processing. For example, if the letters PAN are presented to an English-Spanish bilingual, the possible conceptual meanings for this word will be activated across both languages so that the English definition of a cooking utensil and the Spanish definition of bread will be generated. The definitional meaning most relevant or contextually appropriate wins the competition for activation. As connections between an L1 and L2 become strengthened through proficiency, translation equivalency, or semantic links, the representations from both languages become integrated to form a lateral inhibitory network. With strong connections, information regarding the more dominant

Figure 1 An example of a simple connectionist model. Conceptual nodes feed into larger, more generalized nodes. Thicker lines represent greater association strength, which the model indicates as having a higher degree of connection between the represented concepts.
and proficient language can be more easily inhibited and suppressed during L2 processing to allow for more efficient communication.

2.3. Hierarchical Models

While connectionist models provide an account for how multiple languages can become connected within the mind, hierarchical models offer an alternative account to explain this process using interdependent memory. These models propose the existence of a single store for each language as well as a common store. In addition to processing information of a word from its individual features, combined letter form, and conceptual meaning, hierarchical models also assign a relative weight and location of the L1 and L2 connections between these parts of information.

The revised hierarchical model (Kroll and Stewart 1994) is one of the most cited models in the bilingual language literature. As common to hierarchical models, it is proposed that the shared concepts for words with equivalent meanings are stored in a common conceptual system, but the individual words are divided at the lexical level by language. Importantly, this model suggests that L1 words are directly linked to their meaning in the conceptual store while subsequent languages must route through the L1 to reach the conceptual store.

To explain lexical development and processing in L2 acquisition, the revised hierarchical model predicts that learners initially link the L2 words onto their L1 translations, which are already connected to the conceptual store (see Figure 2). As proficiency develops in the L2, a link directly from its language’s lexical store to the conceptual store is made. Hence a second connection to conceptual meaning is made. However, this L2–conceptual link is weaker than the L1–conceptual link. This unbalanced connection creates asymmetrical mappings between words and concepts in bilingual

![Diagram of the revised hierarchical model](image)

**Figure 2** A conceptual illustration of the revised hierarchical model. Associations between the L1 and the shared conceptual store are stronger than those between the L2 and the conceptual store. The association from the L2 to the L1 is stronger than in the L1 to the L2 direction, indicating the assumption that L2 learning occurs by translating words into the native language.
memory. Support for the asymmetrical mapping assumption has been provided by research on L1 and L2 translational speeds that indicates bilinguals tend to be faster at translating words from an L2 to the L1 (e.g. Tokowicz and Kroll 2007), as the model would assert the L2–L1 direction can occur via a direct lexical access route as opposed to an indirect, conceptually-mediated route.

Although the revised hierarchical model has been widely accepted, it also has its critics. In particular, the concept of asymmetrical mapping has been called into question. Both novice and expert bilinguals have been shown to demonstrate conceptual interference effects within and between languages during a Stroop task, which requires participants to ignore the conceptual meaning of words while only attending to lexical features (Altarriba and Mathis 1997; but see Kroll and Tokowicz 2005, for a counter-argument to this finding). In addition, proficient bilinguals demonstrate priming effects of semantic categorization in the L2–L1 direction, indicating a conceptual link between the languages (Finkbeiner et al. 2004; Wang and Forster 2010). The revised hierarchical model stipulates that newly acquired languages gain meaning by relying on lexical representations. However, these results indicate that bilinguals of all skill levels can form both conceptual and lexical links for L2 words. While this model has been used to guide research on language acquisition, it is important to continue to adapt and generate bilingual and multilingual language frameworks that can encompass the empirical findings in the literature (Brysbaert and Duyck 2010; Brysbaert et al. 2010).

2.4. Model of L3/LN Acquisition

While the underlying assumptions that make up the models discussed above could be expanded to incorporate third language (L3) acquisition and processing, research on multilinguals has indicated that these populations can be unique. Recently, a new model of language acquisition has been proposed that specifically encompasses multilingual (fluency in more than two languages) language processing. This model has been used to emphasize the uniqueness of language acquisition as stemming from a variety of lexical representations becoming interconnected.

The scalpel model (Slabakova 2016) provides a new set of ideas on how existing knowledge of languages can facilitate (or selectively hinder) the learning of a new language. Language processing does not occur in isolation. The concepts of integrating grammars across languages is a primary basis for this model. The model proposes that transference of information between languages occurs with ‘scalpel-like’ precision to extract the relevant grammars that aid in making meaning or translating the present words. This metaphor is used to encompass the notion that the learning of a new language occurs at the level of syntactic and word features by selectively drawing on the properties of languages already in memory. Aspects of a newly acquired language are broken down and compared to already stored languages, and thus can be influenced by linguistic features. Furthermore, this model stipulates that the transfer of knowledge from one language to another does not necessarily occur during the initial acquisition phase. Rather, concepts acquired in any language can influence the encoding and retrieval of other languages, previously stored or to-be-learned.
The scalpel model emphasizes cognitive, experiential, and linguistic influences on new language acquisition such that languages already in memory can both facilitate and interfere with new language acquisition. In this vein, frequency effects become a consideration for language learning. Learning a new language that appears to be similar to an already proficient language in memory can benefit the individual in quickly picking up aspects that are consistent across both. For example, cognates (i.e. words sharing meaning and form across languages; English: *composition* and Spanish: *composición*) tend to be identified in fluent bilinguals faster than they are identified by individuals not fluent in both languages. However, in the case of circumstances when there is a false similarity between languages, interference from stored linguistic information can hinder learning. For example, Bulgarian adolescents learning English as an L2 have been shown to overgeneralize the rules of morphology of their L1 onto their L2 (Harakchiyska 2011). When translating sentences, Bulgarian speakers often extend the rules of pluralization to uncountable nouns that do not have a pluralized form in English as they would in their native tongue. Thus, the sentence ‘I do my *homework* at home’ may be incorrectly written as ‘I do my *homeworks* [sic] at home’. Overall, the scalpel model attempts to incorporate the idea of foundational information transfer between languages as a tool for L3 (or more) acquisition. However, the model acknowledges that there are practical limitations to this transference that can cause issues depending on the specifics of the language combinations.

3. Methodological Considerations for L2 Studies

The brief overview of various models of bilingual and multilingual language processing provided in Section 2 generates an understanding for how the focus of these theoretical models can vary. A main underlying dispute involves the structure of mental lexicons, namely if there exists a single, interdependent store or multiple, independent language stores. At issue is whether the conceptual properties of words are extracted and stored together, independent of language, or are superimposed with specific lexical features. The use of bilingual research has become a valuable tool for assessing and updating assumptions of language processing, in general. Bilinguals are able to represent the meaning of words with multiple lexical codes (e.g. a pet that meows can be labelled as *cat* or *gato* for an English-Spanish bilingual), while monolinguals cannot. By varying the degree of similarity of lexical codes and overlap of processing within an individual, each model’s explanations and predictions will necessarily differ for linguistic aspects such as language acquisition, production, comprehension, memory, and translation abilities.

Advances in technology have allowed these models and their underlying assumptions to be evaluated with greater acuity and precision (see van Heuven and Dijkstra 2010). Section 3 reviews the existing empirical data for the models described above and how these models are able to account for these findings.

3.1. fMRI and ERP

The models of language processing that have gained the most popularity are limited in their predictions of a theoretical structure for how processing occurs. Most do not provide explicit predictions for where in the brain the processing occurs (but see Indefrey
and Levelt 2004, for an attempt to link functional components to theory). However, technologies do allow for language processing to be localized and compared between the processing of an L1, L2, or LN (languages acquired beyond the L2).

Functional magnetic resonance imaging (fMRI) detects changes in blood flow as a proxy to measure brain activity. As blood flow to an area increases, it is taken as an indication that neuronal activity in that area is occurring above the typical resting rate. Although fMRI provides high-quality images that detail where activation is localized, it produces low temporal resolution. Thus, information provided with fMRI is useful for identifying where in the brain neuronal activity is occurring, but not for creating a timeline of activation. Identifying the specific brain structures involved in tasks of reading and listening can allow for a comparison of the processing between languages, ultimately providing support for a single language store or multiple stores.

Event-related potentials (ERPs) are an alternative measure of brain activity in response to a sensory or cognitive stimulus as recorded by changes in voltage. Substantial changes indicate greater neuronal activation. In contrast to fMRI, measures from ERP provide low image resolution but high temporal resolution allowing for the study of rapidly occurring linguistic processing with precise timing of the activation at various stages (Morgan-Short 2014; Morgan-Short and Tanner 2014; Swaab et al. 2012). For models that provide sequential stages or differentiation of lexical properties, and therefore involve a time course of processing, ERPs can be used to evaluate these assumptions. By comparing the results of location activation information from fMRI with the precise timing of neuronal changes from ERP, researchers can generate a detailed understanding for the physical processing of language.

Looking at patterns of brain activity has allowed for the testing of assumptions corresponding to the theoretical considerations presented in Section 2. For example, what happens at a neurological level when translating words between languages? Palmer et al. (2010) addressed this question with fully proficient Spanish-English and English-Spanish bilinguals. Participants were presented with Spanish and English concrete and abstract word pairs with the task of indicating if both words shared a common meaning or not. ERP recordings were taken during the task to examine lexical-semantic activation during word translation. The results showed a larger peak of the N400 (a common marker of semantic activation; see Kutas and Federmeier 2011; see Lau et al. 2008, for a discussion of lexical and semantic aspects of the N400) when translating in the L2–L1 direction, regardless of word type, than in the L1–L2 direction. The authors explained this finding in terms of an asymmetrical link between the L1–conceptual store and L2–conceptual store as proposed by the revised hierarchical model of language processing. The greater L2–L1 activation of the N400, the authors argued, demonstrated the additional semantic activation that needed to occur during a conceptual judgement due to the less direct, and therefore weaker, connections between the L2 and the conceptual store. When the L1 is presented first, there is a more direct and fast link to its translation equivalent in the L2. The path to make a conceptual judgement is primed, thereby reducing the amplitude and effort required of the neurological response. These results are indeed accounted for by the revised hierarchical model that proposes a direct link from the L1 to the conceptual store.

Although much information can be garnered from studying the neurological components of language processing with fMRI and ERP technologies, these methodologies
present several limitations that merit acknowledgment for assessing theoretical assumptions. First, there are practical constraints for the types of tasks that can be performed while participants are connected to the brain-scanning equipment. This physical limitation reduces the number of naturalistic behavioural measures that can be recorded, as these machines often require the participant to minimize motion. Consequently, comparing data obtained about brain activity to behavioural data must be done with caution as natural reading behaviours typically involve more freedom of bodily movement. Second, although information about where and when in the brain linguistic information is processed when performing a particular task can be obtained from these techniques, neither the underlying causes for brain activation patterns nor an evaluation of the process can be observed. Data obtained from fMRI and ERP technologies are used to imply correlations between task performance and neurological activation. Therefore, neurological data alone cannot be used for evaluating causality, as indicated by many of the word identification models. To create a fuller understanding of the data obtained from fMRI and ERP studies, a combination of results with behavioural data from experimental paradigms should be considered (but see Grey et al. 2017; McLaughlin et al. 2004).

Moreover, when interpreting fMRI and ERP data, results indicating an overlap or separation of brain activation do not necessarily imply the absence of an alternative explanation (Hernandez et al. 2005). By considering where language is processed, an understanding of its function and physical structure can be obtained. However, the possibility remains that there is a neural separation of linguistic representations. A localized brain region can account for the processing of an L2 to a differing degree than an L1, or at differing time courses. In other words, while the physical processing of two languages (e.g. letter analysis) may occur in given brain regions with varying degrees of activation, a higher-order representation (e.g. semantic meaning) can overlap between all languages. This disambiguation cannot be clarified using these methods alone.

### 3.2. Behavioural Methodologies

There are many experimental designs that allow for the analysis of behavioural data. Various experimental results obtained using tasks that provide insight into the processing of language through behavioural responses will be discussed in this section, in relation to learning and memory.

Lexical priming, in which the recent experience of a given language input or previously presented word influences the processing of a subsequently presented language or word, has been used to study implicit learning. This learning can occur not only at the level of individual words (e.g. associating the meaning of a presented word with a concept or related words), but also with syntactic structure (Hartsuiker and Bernolet 2017). Languages that are learned in an informal or immersive setting, such as by children at home, often incorporate an implicit understanding for proper syntax by mimicking the sentence structure produced by others. When attempting to learn an L2, information about the syntax of an L1 is often applied to the L2. This can occur even when the proper syntax between languages does not match precisely. Furthermore, bilinguals tend to process phrases across languages faster if the translation is literal or familiar and the sentence structures of both languages match, as opposed to unfamiliar or figurative
meanings (Carrol and Conklin 2015, 2017). The formulaic structure from one language can carry over into another language and can facilitate processing if the structures are equated, but disrupt processing speed if different. Furthermore, the learned structure of an L2 can become formulaic and, when the formula is not followed, language comprehension will require more time and effort. These studies in figurative language, for example, indicate that priming can occur at the multiword level across languages and that familiar phrases can be stored in the mental lexicon as both individual words and as a whole meaningful unit.

A recent study assessing audiovisual speech cues demonstrated how language familiarity and proficiency can moderate speakers’ strategies for processing speech. Barenholtz et al. (2016) had English monolinguals and English-Spanish bilinguals watch videos of balanced (equally proficient in both languages) bilingual speakers in conversation. Participants watched and listened to clips with speakers in either a language in which they were proficient (English) or an unfamiliar language (Spanish or Icelandic) while an infrared-based eye-tracking system recorded their eye movements. An analysis of eye movements indicated that when asked to monitor the conversation, the individual spent the most time looking at the mouth of a speaker if she used an unfamiliar language, but not if the language was familiar. However, when attention was not explicitly directed towards the conversation, eye movements were focused on the mouth as often as they were to the eyes of the speaker, regardless of whether or not the language was familiar. The authors concluded that language familiarity acts as a mediator for attention to enhance perceptual comprehension. This attentional strategy is particularly important when learning to integrate physical speech production (mouth movements) with acoustic information, such as when acquiring a new language (see Lewkowicz and Hansen-Tift 2012, for a similar study on infants with congruent results).

Understanding the role of factors that influence language learning and comprehension, such as familiarity and visual focal points, helps to distinguish the kind of information most relevant to language learning and comprehension at various stages of proficiency. Because the behavioural responses between an L2 learner and proficient speaker differ, consideration for context and degree of experience with a particular language should be considered when evaluating how it is being processed.

4. Distinguishing the Memory Models

Although the extant literature presents multiple models to explain language learning and memory, the underlying assumptions have also been evaluated with scientific research. At this point, it is still unclear exactly how the mental lexicon is structured and where information pertaining to known languages is stored and processed. However, the evidence from cognitive psychology and neuroscience points towards models that combine both integrated conceptual stores as well as language-specific feature stores. Furthermore, how lexical information is engaged within memory is influenced by the specific properties of the language representations. This section explores findings related to how languages are processed in terms of their lexical units and the underlying nature of these representations.
4.1. Findings Related to Levels of Language Representation

Much of the information discussed thus far has primarily focused on language processing at the word level. However, in the real world, language is primarily conveyed by combining words into phrases or sentences. When assessing sentence processing, as compared to word processing, it is important to consider models for their ability to incorporate the enhanced complexity of syntax and grammar, as well as the increased burden placed on working memory to hold more pieces of information simultaneously (Hamrick and Ullman 2016). Data from ERPs have indicated that sentence processing presented between an individual’s languages can vary based on the manner of acquisition for the given language (see Morgan-Short et al. 2012 for a study of adults learning an artificial language). The L1 is typically learned as a child in immersive informal environments, such as the home, where sentence structure and phrasings are spoken by the parents. However, L2 is often acquired through formal schooling where proper syntax and grammar are explicitly emphasized and taught. Regardless of the context in which one learns, there tend to be similar behavioural patterns that demonstrate proficiency. Yet, differing patterns of brain activity between processing languages learned under formal (i.e. explicit), and informal (i.e. implicit) learning conditions indicate language processing differences.

Once a language has been acquired, the frequency with which specific words or phrases are encountered within a language can play a role in linguistic processing or accessibility. That is, words that are commonly encountered tend to be read faster than uncommon words. This general effect is referred to as the word frequency effect. This robust finding has been found in isolated word identification tasks and also word processing tasks involving words in combination (e.g. Monsell et al. 1989; Segui et al. 1982). This effect has largely been studied in monolingual populations, with frequency referring to the commonality of a given word’s occurrence within a language. However, for a fully proficient bilingual, word frequency might depend heavily on the bilingual’s dominant language. Does the word frequency effect occur within and between the bilingual’s languages?

To address this question, Cop et al. (2015) analysed the eye movements of English monolingual and Dutch-English bilinguals while reading a novel. Monolinguals read a text in English while the bilingual group read half of the novel in the L1 and half in the L2. Levels of proficiency were also assessed for each language within the bilingual group. The results indicated that monolinguals and unbalanced bilinguals (having unequal levels of proficiency between an L1 and L2) showed similar sized word frequency effects when reading in their respective L1. However, balanced bilinguals (equally proficient in both languages) showed an even larger effect in both languages.

Cop et al. (2015) also found that bilinguals tended to make more fixations while reading in their L2 as compared to their L1. The increased rate of fixations resulted in a reduction of reading speed and overall longer reading times.Surprisingly, the ability to process high-frequency words quickly decreased in both L1 and L2 as the level of L1 proficiency increased. However, this effect was not influenced by L2 proficiency. The authors argued that this finding could be explained in terms of a weaker association between word form and meaning in an L2 than an L1, which can be affected by...
proficiency level. That is, the more proficient an individual is in each language, the larger the size of the mental lexicon for that language. Because the size of the frequency effect was identical between monolinguals and the unbalanced bilinguals, both of which were only highly proficient in one language, the authors concluded that the same underlying lexical processing mechanisms were operating for both groups. Comparable results have been found using computer connectionist models that support language proficiency resulting from an increased lexicon size as effectively reducing frequency effects for that language (Monaghan et al. 2017). Overall, these results support an interdependent conceptual store in the bilingual lexicon, with size of the mental lexicon as a main factor for enhancing lexical access and thereby the frequency effect. Furthermore, individual differences in lexical processing can arise as a factor of multilanguage processing with respect to language exposure.

4.2. Findings Related to the Nature of Language Representations

Although the structure of language can impact its processing across languages, the inherent properties of the representations play a key role, as well. It has been well-established that word type is an important consideration for understanding language processing in monolinguals to include where attention is directed, processing speed, and ability to recall (for a recent overview of monolingual versus bilingual emotion word processing see Wilck & Altarriba, in press). Similar effects have been found in L2 processing. For example, Sutton et al. (2007) demonstrated that emotion words (e.g. English: sad, Spanish: triste), as compared to neutral words (e.g. English: table, Spanish: mesa), capture attention across languages in highly proficient Spanish-English bilinguals.

Although word type has been shown to influence processing across languages, and emotion words increase selective attention over neutral words, it is not necessarily the case that the degree of emotionality translates well across languages. Altarriba (2003) collected ratings of concreteness (i.e. tangibility of a word), imageability (i.e. how easy it is to picture the word), and context availability (i.e. how easy it is to generate examples of the word) for Spanish concrete (e.g. perro [dog], tijeras [scissors]), abstract (consejo [advice], verdad [truth]), and emotion (e.g., encantado [delighted], miedo [fear]) words from Spanish-English bilinguals. Emotion words produced the lowest ratings of concreteness, but the highest ratings of imageability and context availability. However, when Spanish emotion words were compared to their English translations (e.g. Altarriba et al. 1999), Spanish words had a higher average context availability rating. In other words, Spanish emotion words generated more meanings than their English counterparts. Altarriba argued that words in one language, especially emotion words, may not precisely and singularly translate into another language. If a bilingual’s understanding of concepts in the L1 and L2 differs, then the perceptual representations between an L1 and L2 must also differ.

To investigate the differences in conceptual versus perceptual representations of information across languages, Altarriba and colleagues employed a variety of experimental paradigms using bilingual populations. To examine if bilingual language information is processed according to its higher-level conceptual information or at its lower-level (i.e.
lexical level), a series of eye-tracking studies was performed (Altarriba et al. 1996). Fluent Spanish–English bilinguals read mixed-language sentences while their eye movements were recorded. When the eye focused on a word in the sentence that had a language switched, it tended to produce a longer fixation than if the word was in Spanish (the bilinguals’ L1) and was highly expected based on the contextual cues. For example, it took longer for participants to process the word *dinero* in the sentence ‘He wanted to deposit all of his *dinero* at the credit union’ than if the translated word was the expected English equivalent, *money*, or if there were no contextual cues for the target word. The authors concluded that sentence context and word expectations were influenced by both the conceptual information provided by the context (prediction ability) and the lexical information (word in English or Spanish). The increased processing time required to comprehend sentences that switched from an L2 into the L1, as compared to a purely monolingual presentation, indicated that presentation mode was a crucial factor in reading comprehension. Retrieval of semantic information is dependent on the language in which information is encoded. These findings suggest support for language processing models with assumptions of separate stores for conceptual and lexical information.

In another attempt to provide evidence for a semantic or lexical overlap across languages, Altarriba and Soltano (1996) examined the repetition blindness effect in bilingual memory. Briefly, the repetition blindness effect refers to an individual’s inability to recall the presentation of a repeated word, often explored using a rapid serial visual presentation task, in which words are presented one at a time. Most studies of this effect have been conducted within a single language, although the few experiments using bilingual populations have indicated meaningful differences (see Martin and Altarriba 2016 for a discussion). Altarriba and Soltano were interested in understanding if the conceptual overlap (word meaning) between equivalent translations would be enough to produce the repetition blindness effect, or if lexical overlap (similarity of word form) of the physical features was required. For example, the English word *book* and the French word *livre* both refer to a compilation of words on pages, although the letters that make up the words are not similar. Spanish–English bilinguals were presented with sentences (Experiment 1B) or word lists (Experiment 2) consisting of intermixed Spanish and English words. On half of the trials, a word was repeated in either the same (e.g. *sour–sour*) or the alternative language via its translation (*sour-agrio*), and the remaining trials had no repeated words. Therefore, on trials where the repeated word was in the same language, there would be repetition of both the semantic and lexical code. However, if the repeated word was presented in the alternative language, then the lexical code would differ while the conceptual meaning would remain the same.

The results indicated that a repetition blindness effect occurred when a word was repeated within the same language, but not if the second presentation was a translation equivalent. Regardless of whether the words were presented in the context of a sentence or as seemingly unconnected words in a list, participants were able to recall the occurrence of both word presentations with the same conceptual meaning if the lexical features were distinct. However, in the absence of grammar and syntactical structure, the repetition of a non-cognate word (i.e. translations that share a meaning but not form) across languages aided in the recall of the repeated word. Altarriba and Soltano (1996)
argued that words presented in list form were being processed at a conceptual level, with semantic overlap facilitating translational recall. When assessing words across languages, it appears that overlap of physical features plays a vital role in merging the concepts together as one and producing repetition blindness. In the case of non-cognate translations, both items are easily processed as separate entities, thus enabling recallability for both words even though they share a conceptual meaning. Comparable results indicating that semantic similarity does not aid in generating useful information when reading to any greater extent than does orthographic similarity have been found in Spanish-English bilinguals in eye movements (see for example, Altarriba et al. 2001). Across multiple experiments, Altarriba and colleagues concluded that language processing does not occur solely at the conceptual level and that the physical features of individual words are considered when encoding and retrieving information from the mental lexicon.

5. Conclusions and Suggestions for Future Directions

Language learning and memory has been a popular topic across many domains, including psychology and neuroscience. The research reviewed in this chapter has integrated the findings of language processing with respect to various models of acquisition, storage, and retrieval. Although there are aspects from each model that can be supported, the overall evidence has largely supported those with a single, interdependent language memory store (see French and Jacquet 2004, for further discussion). Data from various tasks, such as code switching (Heredia and Altarriba 2001) and reading (Altarriba et al. 1996; Cop et al. 2015), seem to support assumptions of hierarchical level processing, with the physical features of words being encoded and retrieved separately from the conceptual meanings.

Bilingual speakers have been identified as a useful resource for studying various levels of language representation. This population has the unique ability to garner the same conceptual information from words with orthographically and phonologically distinct features. The research reviewed throughout this chapter indicates that bilinguals can store and utilize two sets of symbols that represent one concept (e.g. Heredia and Altarriba 2001). Capitalizing on this population’s unique mental representations can allow for the disambiguation of semantic meaning versus lexical features. In a monolingual population, these features are inherently overlapping. However, bilinguals are able to map multiple lexical labels onto a single conceptual meaning, thus allowing the possibility to determine the degree of influence on processing from each. Importantly, these can be studied within the same individual and thus within the same language processing system. Engaging bilinguals and multilinguals in research can effectively influence theory on general language processing. The continued use of this population as a research tool in linguistic research is encouraged to aid in the understanding of how language is represented across all individuals and is not limited to benefiting only those with knowledge of more than one language.

Future investigations of language, memory, and learning should continue to explore and obtain support for the various underlying assumptions of the proposed models. Furthermore, the present models should be assessed for reliability and precision with
multilingual populations. Are all consecutively learned languages stored and represented in the mind in the same way as an L1 or L2? Future research should be aimed at providing answers to this and related questions.

REFERENCES


