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The Effects of Linguistic Labels on Object Categorization and Perception

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Graduate Program in Psychology
A thesis submitted in partial fulfillment of the requirements for the degree in Doctor of Philosophy
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Abstract

The linguistic relativity hypothesis (Whorf, 1956) claims that speakers of different languages perceive and conceptualize the world differently. Language-thought interaction is likely to be more complex in bilinguals because they have two languages that could influence their cognitive and perceptual processes. Lupyan's (2012) Label-feedback Hypothesis proposes a mechanism underpinning language-thought interactions, arguing that linguistic labels affect our conceptual and perceptual representations through top-down feedback. This thesis tested the Label-feedback Hypothesis by capitalizing on an interesting feature of Chinese. In English, most nouns do not provide linguistic clues to their categories (an exception is *sunflower*), whereas in Chinese, some nouns provide explicit category information morphologically (e.g., *ostrich* and *robin* have the morpheme *bird* embedded in their Chinese names), while some nouns do not (e.g., *penguin* and *pigeon*). In Chapter 2, I investigated the effects of Chinese word structure on bilinguals' categorization processes in either a Chinese or English-speaking environment with ERP. Chinese-English bilinguals and English monolinguals judged the membership of atypical (e.g., *ostrich*, *penguin*) vs. typical (e.g., *robin*, *pigeon*) pictorial and word exemplars of various categories (e.g., *bird*). Half of the exemplars in each group had a category clue in their Chinese name and half did not. English monolinguals showed typicality effects in categorization RT data, the N300 and N400 of ERP data, regardless of whether the object name had a category clue in Chinese. In contrast, Chinese-English bilinguals showed a larger typicality effect for objects without category clues in their name (e.g., *penguin, pigeon*) than objects with clues (e.g., *ostrich, robin*), even when Chinese-English bilinguals were tested in English. These results demonstrate that linguistic information embedded in object names has an effect on people's categorization processes. Furthermore, linguistic information in bilinguals' L1 has an effect on their categorization processes even when they are using their L2. In Chapter 3, I investigated the effects of Chinese word structure on bilinguals' object perception. A visual oddball detection task with ERP was used where pictures of four birds (*robin*, *ostrich*, *pigeon*, and *penguin*) were used as standards and deviants. In Chinese-English bilinguals that have lived in Canada for a short period of time, the visual mismatch negativity (vMMN) elicited by deviant stimuli was larger for pairs without category clues (*pigeon-penguin*) than pairs with clues (*robin-*

ostrich). In contrast, long-stay bilinguals and English monolinguals showed similar vMMN for the two pairs. These results demonstrate that linguistic information embedded in object names affects people's object perception. The influences of L1 word structure on object perception diminish as bilinguals live in the L2 country for a longer time.

Keywords

Linguistic relativity, bilingualism, linguistic label, word structure, category clue, object categorization, object perception

Acknowledgments

First and foremost, I would like to express my deep and sincere gratitude to my supervisor, Dr. Debra Jared, for giving me the opportunity to do research and providing invaluable support and guidance throughout this research. Without her generous help and encouragement, this thesis would not have been completed. I would also like to thank my advisory committee, Dr. Steve Lupker and Dr. Paul Minda, for their invaluable feedback for my thesis.

To my past and present lab mates: Eriko Matsuki, Nick Anderegg, Taylor Sguazzin, and Maz Mohamed. Thank you for your academic support and help. To the RAs I have worked with, thank you for your help on the data collection, I couldn't have finished the research without your help.

Finally, my great appreciation goes to my parents and my husband, for their support and love throughout my life. 感谢我的爸爸潘清和妈妈夏惠林，以及老公池子安，谢谢你们一直以来的支持！

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1 General Introduction

1.1 The Interaction between Language and Thought

The interaction between language and thought has been discussed for a long time in cognitive psychology. Speaking one or more specific languages has been shown to have an effect on the way we think about reality (see Wolff & Holmes, 2011, for a review). One illustration of the language-thought interaction was provided by Bloom (1981). In his study, he found that Mandarin Chinese speakers had difficulty with counterfactual reasoning. He argued that this was because Mandarin Chinese is a language that has no distinct lexical or grammatical device for counterfactual sentences (e.g., if dogs had no ears, they could not hear), leading its speakers construct schemas specific to counterfactual speech and thought less directly and with more cognitive effort than speakers of languages that do have counterfactual sentences.

Whorf (1940, 1956) suggested that the language(s) one speaks shapes the way one thinks, known as the famous linguistic relativity hypothesis (LRH):

"*The linguistic relativity principle [...] means, in informal terms, that users of markedly different grammars are pointed by their grammars toward different types of observations and different evaluations of externally similar acts of observation, and hence are not equivalent as observers but must arrive at somewhat different views of the world.*" (Whorf, 1940, 1956)

Questions arise from the LRH such as: does language modulate perception? Is language encapsulated or does it interact with other cognitive processes? If so, what is the nature of these interactions and what properties of language bring these interactions to bear? Scholars have debated these questions for decades. Among the early research on language-thought interaction, Whorf's LRH was equated by some researchers with linguistic determinism (e.g., Brown & Lenneberg, 1954; Hoijer, 1954; Lenneberg, 1953), although Whorf himself did not make the deterministic claim (see Pavlenko, 2014). The linguistic determinism claim is that language determines thought. That is, the language we speak constrains our minds and prevents us from being able to think certain thoughts. If a language has no word for a certain concept, then its speakers would not be able to understand the concept. For example, according to the linguistic determinism, Mandarin Chinese speakers would not be able to think counterfactually, because Mandarin Chinese has no grammatical device for counterfactual sentences. This misinterpretation of Whorf's LRH, or the so-called strong version of LRH, has been widely criticized (e.g., Cardini, 2010; Heider, 1972; January & Kako, 2007; Li & Gleitman, 2002; Pavlenko, 2014; Tse & Altarriba, 2008).

Over the past two decades, a milder version of the LRH has regained researchers' interest, which is more in line with Whorf's original proposal. The milder version of the LRH states that language influences thought. Certain properties of a given language of discourse have consequences for patterns of thought about reality. The language we use influences our thought, not because of what it allows us to think, but because of what it habitually forces us to think about. For example, Mandarin Chinese speakers showed weaker counterfactual reasoning ability than English speakers, not because Mandarin Chinese forbids them to think counterfactually, but the lack of counterfactual grammar in Mandarin Chinese makes its speakers not pay as much attention to counterfactual speech and thought as English speakers do. Many studies have provided support for the milder version of the LRH (see Pavlenko, 2014, and Wolff & Holmes, 2011, for reviews). Evidence comes from various perspectives, especially in terms of the temporal world (Boroditsky, 2001; Friedman, 2004; Hannah, 2009; Y. Li, Jones, & Thierry, 2018), spatial world (P. Li, Abarbanell, Gleitman, & Papafragou, 2011; P. Li & Gleitman, 2002), colour terms (Athanasopoulos, 2009; Hu, Hanley, Zhang, Liu, & Roberson, 2014; MacLaury, 1997; Paramei, 2007; Roberson & Davidoff, 2000; Thierry, Athanasopoulos, Wiggett, Dering, & Kuipers, 2009), and object categorization (Casasola, 2005; Edmiston & Lupyan, 2015; Lupyan, Rakison, & McClelland, 2007).

1.1.1 The Label-feedback Hypothesis

More recently, Lupyan (2008, 2012) has proposed a hypothesis that attempts to explain the cognitive mechanisms underpinning language-thought interactions. His label-feedback hypothesis applies insights from interactive models (e.g., McClelland & Rumelhart, 1981) to the issue of linguistic relativity. It proposes that language is highly interconnected with other cognitive processes, and influences other functional networks in a top-down fashion (see Figure 1.1). According to the label-feedback hypothesis, a word label is not simply a means of accessing a concept; rather, its activation affects the representation and perception of the concept. As shown in Figure 1.1 (B), the bidirectional information flow between a concept, the label, and perceptual representations means that the label can provide feedback to the level of conceptual representations and perception, thus, the activation of the label can change the nature of the concept itself. The concept associated with a verbal label may be systematically different than the ostensibly same concept which is not associated with a label. Furthermore, the influence of verbal label is not limited to novel concepts, the representation of highly familiar concepts can be modulated as the label is attached to the concept.

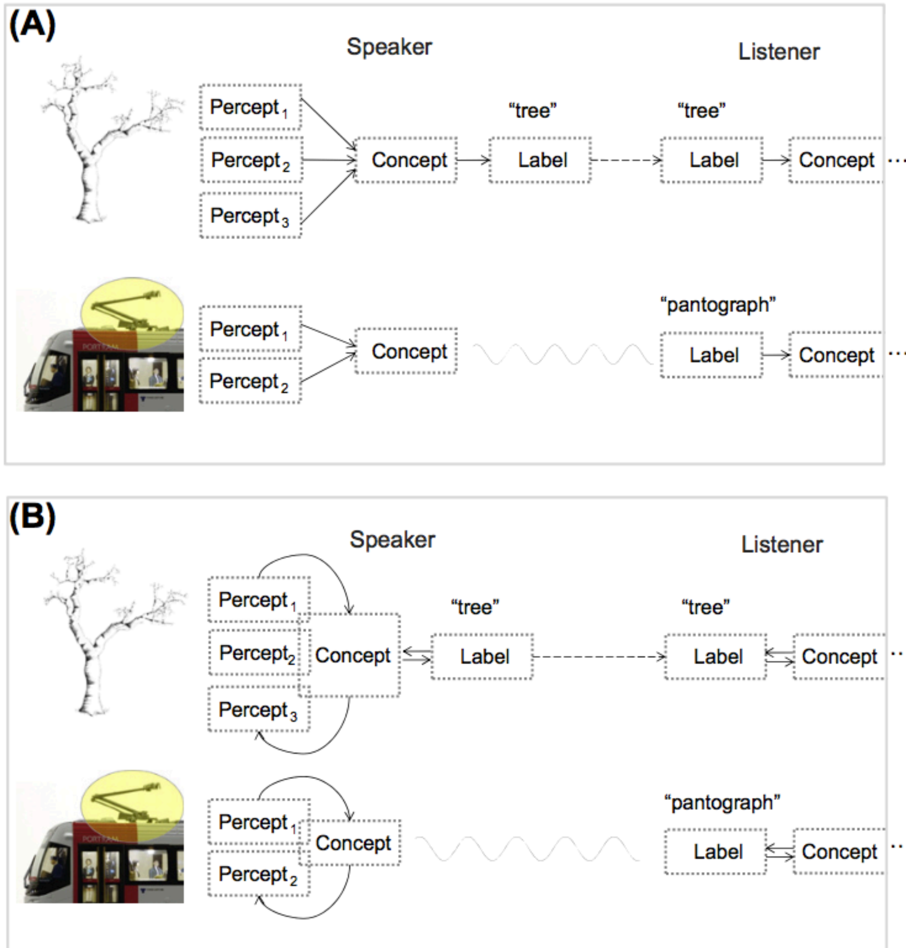

Figure 1.1. The Label-feedback Hypothesis (Lupyan, 2012). (A): A schematic view of the standard account in which a word label is simply a means of accessing a concept. Multiple perceptual exemplars of a concept map onto a common conceptual representation. The concept is further mapped onto a word label, which enables a speaker to activate the same concept in a listener using the label. The one-way connections between representational layers prevent the word label to have an influence on the conceptual representations. (B): A schematic view of the label-feedback hypothesis. All representational layers are recurrently connected, which allows the word label to affect the conceptual representations through feedback.

The Label-feedback Hypothesis makes three broad predictions (Lupyan, 2012). First, associating a label with a concept should affect the acquisition of the concept. Labeled categories should be easier to learn than unnamed categories. Second, the effect of labels should penetrate even perceptual processes. That is, language use can actually affect what we see. Third, named concepts should be activated differently under the on-line influence of the label compared to the same concepts activated by nonverbal means, or when the labels are prevented from affecting the concept. According to the label-feedback hypothesis, the activation of an object's verbal label results in the activation of the most typical or diagnostic features of the category (e.g., the label "car" activates the feature "has wheels" more strongly than the feature "is black"). This top-down activation from verbal labels to features produces a transient "perceptual warping" in which category members that share those features are drawn closer together and non-members are pushed away. In this dissertation, I focused on perceptual features for objects, but there could be feedback from verbal labels to other types of features as well, such as functional features for tools. While the label-feedback hypothesis proposes that the activation of a label has an on-line influence on the representation of the labeled concept and ongoing cognitive processing, it is also possible that through our daily usage of language, the feedback from labels gradually changes the organization of our conceptual representations. Category members become more strongly associated with the most diagnostic features of the category through the feedback from our daily usage of category labels, with the result that category members are represented closer together, and non-members are represented further away from each other.

1.1.1.1 The Role of Labelling in Categorization

There is ample evidence that supports the effect of labelling on categorization. Studies of category learning provide evidence that learning is augmented by language. Categories are learned more effectively when the categories are accompanied by their labels, in infants and toddlers (Fulkerson & Waxman, 2007; Robinson, Best, Deng, & Sloutsky, 2012; Waxman & Markow, 1995), older children (Casasola, 2005; Fulkerson & Waxman, 2007), and adults (Lupyan & Casasanto, 2015; Lupyan et al., 2007). Labels are not only helpful in the case of learning new categories, labels continue to aid categorization even of previously learned very familiar items (Edmiston & Lupyan, 2015; Lupyan & Thompson-Schill, 2012). Once a category is learned, key, diagnostic features of the category are more effectively activated by a verbal label than other highly associated cues, such as nonlinguistic sounds (Boutonnet & Lupyan, 2015; Edmiston & Lupyan, 2015; Lupyan & Thompson-Schill, 2012), and numbers or symbols (Gervits, Johanson, & Papafragou, 2016). For example, in Lupyan et al.'s study (2007), participants learned to categorize “aliens” as those to be approached or those to be avoided with nonsense category labels or other non-linguistic cues present or not. Results showed that learning named categories was easier than learning unnamed categories, and this facilitation effect could not be achieved by providing other non-linguistic cues. Similarly, Lupyan (2008) presented participants with pictures of common objects such as *chairs* and *tables*, and then asked them to label some of them with their basic-level name (e.g., “*chair*”), and to provide a nonverbal response to others (e.g., indicating whether they liked that particular chair or not). In the subsequent recognition memory test, participants had substantially worse memory on the objects they had labeled. This was explained by proposing that labeling resulted in the activation of prototypical features and thus made the representations of stimuli more categorical.

Just as adding linguistic experience can enhance categorization, studies have also suggested that interfering with linguistic related tasks can impair categorization processes (Davidoff & Roberson, 2004; Lupyan, 2009). Individuals with anomic aphasia (a mild type of aphasia where an individual has word retrieval failures and cannot express the words they want to say) showed impaired categorization processes (Lupyan & Mirman, 2013). Additionally, in Perry and Lupyan's study (2014), participants performed a novel perceptual categorization task in which categories could be distinguished by either a uni- or bi-dimensional criterion. They found that participants tend to rely more on complex rules (bi-dimensional solution) when implicit labeling was interfered with using cathodal stimulation over Wernicke’s area. Conversely, participants tend to rely more on a uni-dimensional solution when explicit labeling of the two categories was provided when they were doing the task. This was explained by proposing that labeling facilitated selective representation of the most useful features for categorization.

The effects of labels on categorization seem not to be uniform. A study by Lupyan and Thompson-Schill (2012) suggested that labels affect the most typical category members more than the less typical instances. They conducted a series of cued recognition experiments. On each trial participants heard a cue, either a verbal cue such as “dog” or a non-verbal cue such as a dog bark. Following the cue, participants saw a picture that either matched the cue at the basic level (e.g. a picture of a dog) or did not match (e.g. a picture of a car). Participants had to indicate whether the cue matched the image. The results showed that hearing words led to faster categorization of subsequently presented pictures than hearing non-verbal cues. Additionally, the advantage of verbal cues over non-verbal cues was larger for the more typical, compared with less typical exemplars. The researchers argued that this observation was consistent with the claim of the label-feedback hypothesis that labels activate a representation that emphasizes category-diagnostic features and abstracts over more idiosyncratic features, in other words, typical exemplars of a category. All these studies have suggested that verbal labels have an important role in category formation and object categorization.

1.1.1.2 The Role of Labelling in Object Perception

The label-feedback hypothesis also accounts for the enhanced categorical perception resulting from different ways that languages label objects. Many recent studies have provided evidence in support of this hypothesis in the domains of colour perception (Athanasopoulos, 2009; Athanasopoulos, Dering, Wiggett, Kuipers, & Thierry, 2010; Forder & Lupyan, 2017; Hu et al., 2014; Roberson, 2012; Roberson & Davidoff, 2000; Thierry et al., 2009; Winawer et al., 2007), sound pitch perception (Dolscheid, Shayan, Majid, & Casasanto, 2013), time and spatial perception (Boroditsky, 2001; Boroditsky, Fuhrman, & McCormick, 2011; Casasanto & Boroditsky, 2008; Choi & Hattrup, 2012; Fuhrman et al., 2011; Lai & Boroditsky, 2013; Y. Li et al., 2018), and object perception (Boutonnet, Athanasopoulos, & Thierry, 2012; Boutonnet, Dering, Viñas-Guasch, & Thierry, 2013; Jouravlev, Taikh, & Jared, 2018; Masuda et al., 2017). The evidence that provides support for the language and perception interaction comes from both behavioural studies and electrophysiological studies. Some of the studies have used event-related brain potentials (ERPs) and a visual oddball paradigm (e.g., Boutonnet et al., 2013; Jouravlev et al., 2018; Thierry et al., 2009).

In a visual oddball paradigm, participants identify infrequent visual target stimuli within a continuous flow of rapidly presented stimuli. The critical stimuli in this design are nontarget stimuli. Within the critical stimuli, a standard stimulus is presented with a high local probability (e.g., 80%), and a deviant stimulus is presented with a low local probability (e.g., 15%). The presentation of a deviant stimulus in a sequence of standards is known to evoke a visual mismatch negativity (vMMN) response in an early time window (usually peaking at around 150 to 250 ms, see Czigler, 2014; Pazo-Alvarez, Cadaveira, & Amenedo, 2003, for reviews). The finding has been interpreted as indicating that the vMMN is purely perceptual, because it was believed that specific lexical information is unlikely to be available in this early time window (Strijkers, Holcomb, & Costa, 2011; Thierry, 2016). The vMMN is assessed by comparing the average amplitude of the waveform for the deviant in the time window of interest to that for the standard. To ensure that these comparisons reflect deviancy and not inherent perceptual differences between the standards and deviants, studies typically counterbalance stimuli such that a stimulus that is a standard in one block of trials is the deviant in a second block, and data are averaged across the two blocks. The magnitude of vMMN has been broadly used as an index of perceived difference/similarity between objects.

For example, Thierry et al. (2009) used a visual oddball paradigm to test the effects of language on colour perception. They tested English and Greek individuals, who differ in how they label the colour blue. Greek differentiates a darker blue called *ble* and a lighter blue called *ghalazio*. However, this differentiation does not exist for dark and light green. A visual oddball detection task was used where shades of dark and light blue were used as standards and deviants in two experimental blocks, shades of dark and light green were used in two other blocks. Results showed that the vMMN effect (deviants elicited a more negative vMMN than standards) was larger for dark and light blues than for the greens in Greek participants, but this difference was not observed in English participants, suggesting that using two labels for the colour *blue* made Greek speakers perceive a greater difference between light and dark blues than English speakers.

In a more recent study, Boutonnet et al. (2013) investigated the effects of labeling on object perception using a visual oddball paradigm. English has two words refer to a *cup* and a *mug*, while Spanish only uses one label *taza* for these two objects. Pictures of cups and mugs were used as standards and deviants in the oddball detection task. Results showed that the vMMN effect was larger in English compared to Spanish participants, suggesting that English speakers perceived a greater difference between the two objects than Spanish speakers. According to the label-feedback hypothesis (Lupyan, 2012), when the standard and deviant objects share a verbal label (e.g., *taza* for Spanish speakers), the perceptual features that are activated by top-down feedback from the label are largely overlapped for the standard and deviant objects, causing them to be perceived more similarly.

More recently, Jouravlev et al. (2018) used a visual oddball paradigm to investigate the perception of objects that share a common verbal label but belong to different conceptual categories. In their Experiment 1, pictures of *orange* as a fruit and *orange* as a colour were used as critical stimuli. Pictures of an *apple* and colour *red* were used as controls. In Experiment 2, pictures of *bat* as an animal and as a baseball bat were used as critical stimuli. Pictures of a *bird* and a *hockey stick* were used as controls. Results showed that native English speakers had a larger vMMN effect for controls than critical stimuli pairs, suggesting that English speakers perceived two objects as more similar if they share a label even when the two objects are very dissimilar and from different conceptual categories.

In conclusion, the label-feedback hypothesis has provided a new perspective on the language-thought interaction. It is clear that verbal labels play an important role in category formation, categorization processes, and object perception. However, to my knowledge, there have not been many studies that have combined the label-feedback hypothesis with bilingualism. The majority of the research has focused on monolingual groups, despite the fact that more than half of the world's population is bilingual. Although a number of models of bilingual language processing and bilingual memory have been put forward, we still do not know much about the interaction between language and thought in a bilingual's mind. The issue of language-thought interaction in bilinguals has become increasingly important.

1.2 Bilingualism and Bilingual Mental Models

It is estimated that more than half of the world's population are bilinguals (Grosjean & Li, 2013). Grosjean (1989) suggested that bilinguals are not simply "two monolinguals in one". Over the past decades, researchers have investigated whether bilinguals selectively active only the language in use or whether activation is nonselective. Most of the existing studies provided supporting evidence for the nonselective activation view: bilinguals activate information from both of their languages simultaneously even when they are using only one of their languages. The activation of the language not in use either facilitates or interferes with the processing of the target language that is used at the moment (e.g., Dijkstra, Van Heuven, & Grainger, 1998; Grainger & Dijkstra, 1992; Jared & Kroll, 2001; Kroll & Stewart, 1994; Misra, Guo, Bobb, & Kroll, 2012; Nakayama, Sears, Hino, & Lupker, 2013; Wu & Thierry, 2010). This cross-language interaction in bilinguals' everyday life can change the ways bilingual's languages are processed and the way concepts are represented in their minds. The interaction of bilinguals' two languages has led bilingual researchers to hypothesize about how bilinguals might represent their two languages in memory. The question of whether bilingual's two languages are represented in two separated language-specific stores or just one integrated, language-independent store has been one of the central issues in the bilingual literature. There have been several models of bilinguals that have proposed ideas about lexical representations (labels) in each language and their relationship to conceptual representations.

1.2.1 Bilingual Interactive Activation Plus Model

The Bilingual Interactive Activation Plus Model (BIA+; Dijkstra & Van Heuven, 2002) describes bilingual visual word recognition and captures the non-selective lexical activation in bilingual language processing. In this model, two subsystems exist: a word identification subsystem and a task/decision subsystem. In the word identification system, there are four levels of representation: sublexical orthography and phonology, orthography and phonology of whole words, language nodes indicating language membership, and word semantics. The model is interactive in the sense that representations at a particular level can activate and inhibit representations at adjacent higher or lower levels. In visual word recognition, the sublexical representations activate corresponding whole-word lexical representations, which then activate relevant semantic representations as well as language nodes that indicate membership in a particular language. All of the information from the word identification subsystem is then used in the task/decision subsystem to carry out the remainder of the task at hand (e.g., word identification), such as which action must be executed.

Many studies have provided supporting evidence for the BIA+ model. The effect of interlexical homographs has been used to support the assumption of non-selective lexical access (Beauvillain & Grainger, 1987; De Groot, Delmaar, & Lupker, 2000; Dijkstra, Jaarsveld, & Brinke, 1998; Jared & Szucs, 2002; Jouravlev & Jared, 2014; Lemhöfer & Dijkstra, 2004). Interlexical homographs are words with the same written form but different meanings in the two languages of the bilingual (e.g., *pain* means "hurt" in English, but "bread" in French). These studies have found that bilinguals responded differently in terms of response time and percentage errors between homographs and their controls, indicating the involvement of the non-target language in the experimental task. Additionally, cross-language priming effects have also provided supporting evidence for non-selective lexical access. Studies have found phonological priming effects from both L1 primes to L2 targets and L2 primes to L1 targets (e.g., Ando, Jared, Nakayama, & Hino, 2014; Ando, Matsuki, Sheridan, & Jared, 2015; Brysbaert, Van Dyck, & Van de Poel, 1999; Haigh & Jared, 2007; Jouravlev, Lupker, & Jared, 2014; Van & Brysbaert, 2002; Zhou, Chen, Yang, & Dunlap, 2010), as well as orthographic priming and translation priming from both L1 to L2 and L2 to L1 (e.g., Bijeljac-babic, Biardeau, & Grainger, 1997; Jouravlev et al., 2014). The BIA+ model proposed detailed assumptions regarding lexical access in bilingual word recognition. However, the model has little to say about how conceptual information is represented, beyond the assumption of a semantic store that has bi-directional links to lexical representations in both languages.

1.2.2 The Revised Hierarchical Model

The Revised Hierarchical Model (RHM; Kroll & Stewart, 1994) is a model of bilingual memory. This model distinguishes between the lexical level and the conceptual level, and focuses on the mapping between lexical and conceptual stores. The RHM assumes that bilinguals organize their languages in two separate lexicons with one shared conceptual system. Importantly, the RHM proposes asymmetrical connections between bilingual memory representations. At the lexical level, the connection from L2 to L1 is stronger than that from L1 to L2 because L2 to L1 is the direction in which second language learners first acquire the translations of new L2 words. The link between a shared concept and the L1 lexicon is stronger than the link between a shared concept and the L2 lexicon (see Figure 1.2). The RHM assumes that when a person first learns a second language, there is already a strong link between the L1 lexicon and conceptual representations. L2 words are attached to the system by lexical links with L1. As bilinguals become more proficient in L2, direct conceptual links are also acquired, but are still weaker than the link between L1 lexicon and the shared concept. Based on the asymmetrical connections, the RHM proposes different pathways for L2-L1 translation and L1-L2 translation: a direct lexical link from L2 to L1, but an indirect conceptual link from L1 to L2, by way of the concept.

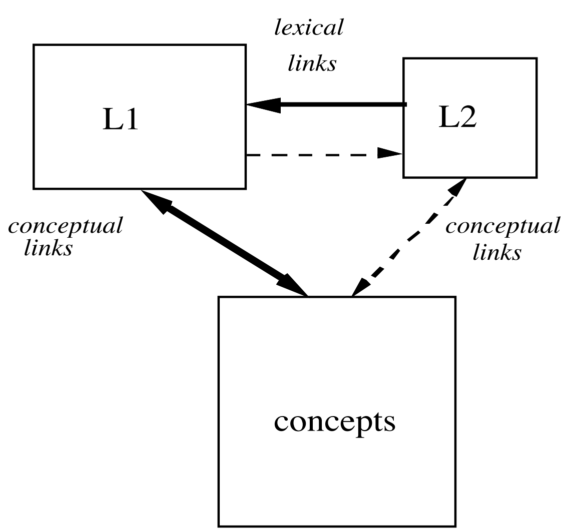

Figure 1.2. The Revised Hierarchical Model (Kroll & Stewart, 1994).

Many studies have supported the idea that there are asymmetrical connections between L1 and L2. A frequently used task is to give participants a word in one language and ask them to translate it into their other language. An asymmetrical translation effect is typically found in which translation from L2 to L1 is faster than translation from L1 to L2 (Chen, Cheung, & Lau, 1997; Cheung & Chen, 1998; Kroll & Stewart, 1994; Sánchez-Casas, Suárez-Buratti, & Igoa, 1992). In addition, conceptual factors (e.g., concreteness of a word) were found to affect translations from L1 to L2, but not L2 to L1 (Kroll & Stewart, 1994; Sholl, Sankaranarayanan, & Kroll, 1995), supporting the assumption that L2 to L1 translation goes through a direct lexical link, but L1 to L2 translation encompasses an indirect conceptual link. The RHM proposed detailed assumptions regarding to the mapping between lexical and conceptual stores in bilingual memory. However, this model does not provide any insight into the nature of bilingual conceptual representations. Recently, Dijkstra et al. (2018) proposed a new computational model: Multilink which integrated basic assumptions of both the BIA+ and RHM. Multilink has been shown to successfully simulate bilingual word recognition and word translation (Dijkstra et al., 2018). However, all these models (RHM, BIA+, and Multilink) put aside the nature of conceptual representations. Concepts are represented in a “black box” in these models.

1.2.3 Distributed Conceptual Feature Model

The Distributed Conceptual Feature (DCF) model (De Groot, 1992) is another model of bilingual memory. Unlike the RHM, this model focuses on the nature of bilingual conceptual representations and elaborates on how translations that are not entirely equivalent in meaning may be represented in the conceptual store. The DCF model proposes that concepts are represented by sets of semantic features. In this account, translation equivalent words differ in the extent to which they activate the same semantic features. Some translation equivalent pairs activate all or most of the same features, whereas others activate only some of the same features. They would have more semantic features in common if the underlying concepts are similar in two languages (e.g., “dog” in English and “chien” in French share most of their features: has four legs, barks, etc.). On the other hand, translation equivalents would exhibit more language specific features if the concepts are dissimilar in two languages (e.g., “dragon” in English has some English specific features, like has wings, that are not shared by “龙” in Chinese). The DCF model also assumes that translation pairs that are concrete words and cognate words may share more semantic features than pairs that are abstract words and noncognate words. Therefore, concrete and cognate words are more likely to be very similar in meaning across languages, whereas abstract words are more likely to activate language specific information.

Evidence for this model generally comes from studies that show a concreteness effect in bilingual word recognition and translation (De Groot, 1992; Heredia, 1995; Van Hell & Groot, 1998). Bilinguals are assumed to recognize and translate concrete words faster than abstract words because access to shared conceptual information is more available for concrete words than abstract words. The DCF model provides some insights into the question of how concepts are represented in bilingual’s mind, and shows how translations that are not entirely equivalent in meaning might be represented in bilingual’s mind. However, it lacks a developmental account as to how bilinguals develop conceptual representations as they become more proficient in L2 and more often exposed to an L2-speaking environment.

1.2.4 Shared (Distributed) Asymmetrical Model

The Shared (Distributed) Asymmetrical (SDA) model (Dong, Gui, & MacWhinney, 2005) is a more recent model about bilingual conceptual representations. Like the DCF model, the SDA model assumes that concepts are represented by sets of semantic elements. Translation equivalent words are assumed to have links to both common elements that are shared across different languages and language-specific elements. For example, the word *dragon* and the Chinese translation *龙* may share common conceptual elements such as “breathes fire”; other elements such as “has wings” are considered as language-specific because they are true in Western culture but not in Chinese culture. Taking a step further from the DCF model, the SDA model encompasses a developmental account regarding how the connection strengths between words and semantic elements change as bilinguals become more proficient in L2. The model assumes that when first acquiring a second language, the L2 learner starts by assuming the representation of an L2 word has all the elements of its translation equivalent in L1. As the bilingual becomes more proficient in L2, the link between L2 words and L1-specific elements is gradually eliminated as the link between L2 words and L2-specific elements is added and gradually strengthened. The acquisition of L2-specific elements can also result in bilinguals developing connections between L1 words and L2-specific elements (see Figure 1.3).

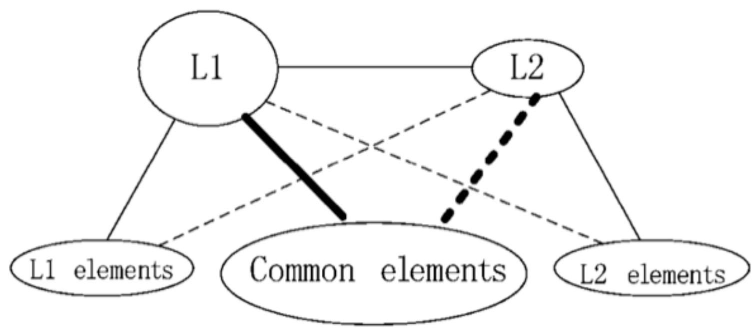

Figure 1.3. The Shared (Distributed) Asymmetrical Model (Dong, Gui, & MacWhinney, 2005). The symbols L1 and L2 stand for particular L1 and L2 words. L1 and L2 elements stand for semantic elements that are specific to one language. Common elements stand for semantic elements that are shared across languages.

Supporting evidence for the SDA model comes from Dong et al.'s study (2005). In this study, participants were asked to rate the semantic similarity of culturally-loaded word pairs (e.g., *red* and *bride* are highly related in Chinese culture but not in Western culture). Chinese-English bilinguals with different English proficiency were tested, as well as Chinese and English monolinguals. The results showed that when tested in English, the rating patterns of highly proficient bilinguals resembled English monolinguals more than the rating patterns of low proficiency bilinguals, suggesting that highly proficient bilinguals developed new links between L2 words and L2-specific elements, and thus performed more like English monolinguals in the task. On the other hand, when tested in Chinese, the rating patterns of highly proficient bilinguals deviated from Chinese monolinguals more than low proficiency bilinguals, suggesting that highly proficient bilinguals developed new links between L1 words and L2-specific elements, and thus performed less like Chinese monolinguals.

To summarize, there are several strong models of bilingual language processing and bilingual memory. They have described how the lexicon and concepts are represented in a bilingual's mind, and how lexical and conceptual representations are linked. Each model has received supporting evidence from various studies. The DCF and SDA models (DeGroot, 1992; Dong et al., 2005) are most like the model assumed in the label-feedback hypothesis except that they have two lexical stores instead of one. However, the proponents of these bilingual models did not make any hypotheses concerning how lexical representations might influence the organization of semantic features. As mentioned before, the label-feedback hypothesis assumes that a word label is not simply a means of accessing a concept; but it can affect the representation of the concept through activating the most typical features of the concept. Although this idea was originally developed in monolinguals, it can provide some new insights into bilinguals too. A bilingual's conceptual organization can be different from monolinguals in each language due to the influence from both of their languages. Studies investigating naming patterns of common household objects in bilinguals and monolinguals have suggested that bilinguals describe existing categories differently from monolinguals in both their first and second languages. (Ameel, Malt, Storms, & Van Assche, 2009; Ameel, Storms, Malt, & Sloman, 2005; Malt, Li, Pavlenko, Zhu, & Ameel, 2015; Malt & Sloman, 2003; Pavlenko & Malt, 2011). For example, in Pavlenko and Malt's study (2011), Russian-English bilinguals were asked to name images of 60 common drinking containers, in which some containers were categorized differently between Russian and English monolinguals. For example, English *cup* is used more broadly than its Russian translation *chashka.* Two containers that both are called *cup* in English can be labelled differently in Russian: one is called *stakan* and the other is called *chashka*. The results showed that early bilinguals' naming patterns for their two languages were more similar to each other compared to the naming patterns observed in monolinguals in each language. For example, early bilinguals used *chashka* for some of the *stakans* when naming in Russian, resembling English speakers' naming pattern. Pavlenko and Malt argued that early bilinguals' lexical conceptual representations have converged across languages resulting from the combination of two inputs in their childhood environment. In another study, Ameel et al. (2009) found evidence for converging category centers and boundaries for Dutch-French bilinguals. Participants rated the typicality of various items from two categories (bottles vs. dishes). The results showed that category centers (prototypes of one category) in the bilingual's two languages were situated closer to each other than were the corresponding monolingual category centers. The researchers concluded that category representations in a bilingual's mind are highly influenced by convergence, that is, the category structure in a bilingual's mind is largely distinct from that of monolinguals in either language. The category structure changes with language input, but the changes are longer term that the temporary perceptual warping assumed by Lupyan (2012).

Some other studies on colour representation and colour perception have also demonstrated the complexity of language-thought interaction in bilinguals. In a study on colour representation, Athanasopoulos (2009) showed that advanced Greek-English bilinguals shifted their colour prototypes to form a new representation of colour categories that was different from their monolingual counterparts in each language. The shift was a result of learning an L2 that does not make a lexical distinction that is made in L1 (English has the term *blue*, but Greek uses *ghalazio* and *ble* for light and dark blue, respectively). In another study, Athanasopoulos et al. (2010) investigated whether exposure time to an L2 (English) environment in Greek-English bilinguals affects their colour perception. A visual oddball detection paradigm was used where shades of dark and light blue were used as standards and deviants in two experimental blocks, shades of dark and light green were used in two other blocks. Greek-English bilingual participants were divided into two groups based on the amount of time they had lived in an English-speaking country. Results showed that short-stay bilinguals showed larger vMMN effects for dark and light blues than for greens, while long-stay bilinguals did not, resembling English monolinguals. The results suggested that in the process of mastering English and immersing in an English-speaking environment, Greek-English bilinguals gradually lose the *ble/ghalazio* distinction. Therefore, there are reasons to believe that the effects of languages may be more complicated in bilinguals than in their monolingual counterparts.

Language-thought interaction in bilinguals is a compelling question that needs to be investigated more thoroughly.

1.3 Research Questions

The main objective of my dissertation is therefore to better understand the language-thought interaction in a bilingual's mind, at the same time testing the label-feedback hypothesis from a new perspective. While verbal labels are known to play an important role in conceptual representations and perception, the influence of the characteristics of the verbal label itself, like the structure of a verbal label, has received less attention. Words can be constructed in different ways. For example, compound words are formed by combining two individual words together (e.g., watermelon). In Mandarin Chinese, most nouns are compound words, and they provide explicit category information morphologically. Most of the items within one category share a common root morpheme which provides explicit cues to their super-ordinate categories. For example, most bird names share the morpheme "鸟" in Mandarin, which means bird (e.g., robin, 知更鸟, woodpecker, 啄木鸟, ostrich, 鸵鸟, etc.). On the other hand, in English, most nouns do not provide linguistic cues as to their categories. For example, most bird names in English do not have the category name "bird" in them (e.g., robin, woodpecker, ostrich, etc.), although a few do (e.g., bluebird). The category cue embedded in objects' Chinese names provides category information both orthographically and phonologically. The category morpheme is pronounced when spoken, just like the English word *bluebird*.

My dissertation investigated the influences of word structure on object categorization and object perception by capitalizing on the differences in the way that nouns are constructed in Mandarin Chinese and English. In Chapter 2, I used event-related potentials (ERPs) to examine the effects of word structure on object categorization in Mandarin-English bilinguals. In Chapter 3, I used ERPs to investigate how word structure affects object perception. The general discussion integrates both of the studies into a series of conclusions and suggestions for future studies on language-thought interaction in bilinguals.

1.3.1 How Does Word Structure Affect Object Categorization in Bilinguals?

In Chapter 2, I investigated how word structure affects object categorization in bilinguals. Past research has provided much evidence that verbal labels have an important role in category formation and categorization processes (e.g., Edmiston & Lupyan, 2015; Lupyan & Casasanto, 2015; Lupyan & Thompson-Schill, 2012). Associating a label with a category could facilitate the acquisition of the category (e.g., Lupyan et al., 2007). The involvement of category labels in categorization processes could result in enhanced categorization performance, but poorer ability to make within-category distinctions (e.g., Lupyan, 2008). However, to my knowledge, most research has focused on the advantage of verbal labels over no label present or other non-verbal cues in categorization. Few studies paid attention to the potential effects of word structure on categorization processes. In addition, most of the previous studies focused on monolingual groups. The question of how word structure affects object categorization in bilinguals is still unknown.

In Experiment 1, I used ERPs to examine the effects of Chinese word structure on bilinguals' categorization processes in either a Chinese or English-speaking environment. Of interest was whether category information in an object's Chinese name facilitated categorization of the object in both Chinese and English-speaking environments. In Experiment 2, I used ERPs to further examine the effects of Chinese word structure on bilinguals' categorization processes when bilinguals were put into a strong English monolingual mode. Of interest was whether category information in an object's Chinese name facilitated categorization of the object in a pure English-speaking environment where no clue showed that Chinese was involved.

1.3.2 How Does Word Structure Affect Object Perception in Bilinguals?

In Chapter 3, I used a visual oddball paradigm to investigate how word structure affects object perception. Research has suggested that the effects of a category label could penetrate perceptual processes such that a category label affects categorical perception. Other studies using this paradigm have shown that sharing a verbal label in two objects enhanced perceived similarity of the two objects (e.g., Boutonnet et al., 2013; Jouravlev et al., 2018). When a label is activated, top-down processing would highlight the typical or diagnostic features for the labelled category, minimizing within-category differences, thus enhancing the perceived similarity of two objects sharing the same name. However, like studies investigating the effects of labels on categorization, most research on the language-perception interaction has focused on the effect of two objects sharing an identical label, but does not take word structure into account. Therefore, in the second study of my dissertation, I further investigated the effects of word structure on object perception in Chinese and English speakers by using ERPs. Specifically, of interest was whether sharing a category level cue in typical and atypical exemplars' verbal labels enhances the perceived similarity of the objects. Furthermore, research has shown that immersion in an L2-speaking environment makes bilinguals less sensitive to the linguistic distinctions that exist only in their L1 (e.g., Athanasopoulos, 2009; Athanasopoulos et al., 2010). Thus, in the second study of my dissertation, I also tested Chinese-English bilinguals who have lived in Canada for a relatively long time, to see if the experience of immersing in a second language-speaking environment diminishes the influences from bilinguals' first language on object perception.

To summarize, a full understanding of language-thought interaction must not just take into account the difference between cognitive processes accompanied by a verbal label vs. no verbal label present, but also take into account the effect of characteristics of a label itself. In addition, the language-thought interaction in the minds of bilinguals still needs further investigation. It could be different from and more complex than language-thought interaction in monolinguals. The aim of the present review was to identify shortcomings in research in this field. Although there are a number of current models that have been developed in bilingual language processing and conceptual representation, it is still unclear how bilingual's two languages interact with concepts in bilingual's mind.

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2 The Effects of Word Structure on Object Categorization

Linguistic labels have been shown to have an important role in categorization processes (e.g., Edmiston & Lupyan, 2015; Lupyan & Casasanto, 2015; Lupyan & Thompson-Schill, 2012). However, to my knowledge, most of the existing studies have focused on the advantage of verbal labels over other non-verbal cues. Few studies have considered whether the characteristics of the verbal label itself, like the structure of a verbal label, could have an influence on categorization. A possible way of exploring this question is to use cross-linguistic differences in verbal labels. Words expressing the same concept can be constructed in different ways in different languages.

A study by Liu et al. (2010) investigated the effects of a verbal label on categorization by capitalizing on differences in the way that words are constructed in Chinese and English. In English, most nouns do not provide linguistic clues to their categories (exceptions are *sunflower* and *bluebird*), whereas in Chinese, most nouns provide explicit category information morphologically (e.g., the morpheme 鸟 *bird* in the noun 鸵鸟 *ostrich*). Images of objects that have category level cues in their Chinese names were used as critical stimuli. Native speakers of Chinese and English were presented with category labels followed by images of typical and atypical exemplars and non-category exemplars of a category. Participants were asked to judge the membership of the pictures while their EEG brainwaves were recorded. Generally, atypical items are categorized with more difficulty than typical items, which is called the typicality effect (Rosch, 1975; Rosch, 1973). Previous studies investigating the typicality effect with ERPs have found that the typicality effects in pictorial stimuli are marked by the negative N300 component (Hamm, Johnson, & Kirk, 2002; Hauk et al., 2007; Kiefer, 2001; McPherson & Holcomb, 1999). In addition, other studies have suggested that N400 and a late positive component are also involved in the typicality effect (Federmeier & Kutas, 2001; Ganis, Kutas, & Sereno, 1996; Hamm et al., 2002; West & Holcomb, 2002).

In Liu et al.'s study (2010), English speakers showed significant N300 and N400 differences between typical and atypical exemplars, whereas Chinese speakers showed no such differences. The authors argued that the absence of a typicality effect in Chinese speakers demonstrated that the category cue provided in nouns facilitated the categorization process for these speakers and reduced the influence of typicality, even though the stimuli were pictures, not words. Liu et al. (2013) further tested this effect by using functional magnetic resonance imaging (fMRI). The results were consistent with their previous study in that English speakers showed a typicality effect in the left inferior frontal gyrus and the bilateral medial frontal gyrus while Chinese speakers showed no such effects, presumably as a result of facilitation from the category level cue in the pictured object's Chinese name. Liu et al. argued that these results suggested that languages change the way people access semantic information. When categorizing atypical exemplars, English speakers needed additional semantic processing to make the right decision, while Chinese speakers were able to bypass the additional semantic processing because of the category information in objects' Chinese names. However, Liu et al. neither specify what is involved in the additional semantic processing, nor did they propose a mechanism for their findings.

The label-feedback hypothesis (Lupyan, 2008, 2012) provides a mechanism to account for Liu et al.'s (2010) findings. The key assumption of the hypothesis is that the activation of an object's verbal label can send feedback to perceptual features associated with the label, especially the most typical or diagnostic features of the object category. There are two ways to understand the findings based on the label-feedback hypothesis. First, participants' ongoing categorization processing could be influenced by the feedback from the on-line activation of the category label and the object label in the categorization task. More specifically, in Liu et al.'s study (2010), participants first saw a category label which was followed by an object picture. They made judgements as to whether the object picture was an exemplar of the category. Based on the label-feedback hypothesis, the category label would have activated a range of typical features of the category. For example, the category label *bird* would have activated features like has wings, has feathers, etc. Then the target picture is presumed to quickly activate its corresponding name, or label, and the label would then activate a range of features of the object. For example, a picture of robin would activate the label *robin* quickly, then the label *robin* would activate a range of features like has wings, has feathers, red belly, etc.;

an ostrich picture would activate the label *ostrich*, which would then activate features like has wings, cannot fly, runs fast, etc. It would be easier to categorize a typical object than an atypical one, because the features activated from the category label overlapped more with the features activated for a typical exemplar than an atypical one. For example, the features activated from the label *bird* overlapped more with features activated for a *robin* than features activated for an *ostrich*. If an object's Chinese name has the category cue embedded, then this explicit category clue would facilitate the activation of the most diagnostic features of the category, even when the object is an atypical exemplar of the category. For example, the morpheme *鸟 (bird)* embedded in the Chinese label *鸵鸟 (ostrich)* would make the diagnostic features of the category bird more available, like has wings, has feathers. Therefore, the perceptual features that were activated from a category label would have more overlap with the features activated from the feedback from a label with category cue than a label without cue, thus producing a faster response and less negative N300 and N400.

This explanation assumes that the verbal label of the target object is activated quickly when the picture is presented and then the activation of the object label influences the categorization decision. However, it is not clear whether pictures would activate their corresponding names quickly enough in a categorization task. Previous studies have found that pictures could be categorized faster than they were named (Fraisse, 1968; Irwin & Lupker, 1983; Potter & Faulconer, 1975). In addition, more recent ERP studies have suggested that lexical information becomes available at around 200 ms after stimulus onset in a picture naming task (Costa, Strijkers, Martin, & Thierry, 2009; Indefrey & Levelt, 2004; Strijkers, Costa, & Thierry, 2010), and a bit later at around 350 ms in an object categorization task (Strijkers, Holcomb, & Costa, 2011), while the typicality effects usually show up at around 300 ms in tasks with picture targets (e.g., Hamm et al., 2002; Hauk et al., 2007). Therefore, an alternative way to understand Liu et al.'s (2010) findings is that the organization of category representations in Chinese speakers could have been changed under the long-term influences from the feedback from everyday usage of objects' Chinese labels. More specifically, through the feedback from daily usage of Chinese labels, category members that have a category cue in their

Chinese names become more strongly associated with the most diagnostic features of the category, resulting in them being stored closer together in the center of the category space, while members that do not have a category cue in their Chinese names are stored in the periphery of the category space. For example, every time bilinguals use the Chinese label *鸵鸟 (ostrich)* to refer to an ostrich in their daily lives, the category cue *鸟 (bird)* embedded in the label would send feedback to the conceptual representations, resulting in the diagnostic features of the category bird being activated to a stronger degree, making it share more features with a typical bird (e.g., robin). Through years of influences from the Chinese label *鸵鸟 (ostrich),* the conceptual representation of an ostrich in Chinese speakers would be stored closer with typical birds (e.g., robin) in the center of the bird category, thus making it easier to categorize an ostrich as a bird. On the contrary, the atypical bird *penguin* does not have a category cue in its Chinese name; the diagnostic features of the category bird would not get booster activation every time the label was used. As a result, the conceptual representation of a penguin would be stored at the periphery of the category bird, further away from typical birds, making it difficult to categorize a penguin as a bird, thus producing a slower response and more negative N300 and N400.

In summary, Liu et al.'s studies (2010, 2013) have suggested that our categorization processes are affected by the languages we use. They are not only affected by whether or not an object has a verbal label, but also by characteristics of the verbal labels. As aforementioned, Lupyan and Thompson-Schill (2012) suggested that labels affected the most typical category members more than the less typical instances, but this claim ignores different structures of word labels. On the other hand, studies by Liu et al. (2010, 2013) have suggested that labels could have a key role in categorizing atypical items if the label contains an explicit category cue.

2.1 Rationale for the Present Study

The present study extended the current literature by examining the effect of label structure on the typicality effect in categorization. More specifically, the study investigated whether having a category level cue in an object's verbal label results in it being categorized more easily, especially when the object is an atypical exemplar of the category. The present study extended Liu et al.'s studies (2010, 2013) in several ways. A limitation of Liu et al.'s work is that they did not include exemplars without a category cue in their names for comparison. Such stimuli are needed to show that Chinese speakers are indeed sensitive to typicality when no category cue is available. Here in the current study, an equal number of exemplars that did and did not contain a category cue were included. A second limitation of Liu et al.'s work is that only five categories and ten stimuli were included in the ERP study. Each stimulus was presented ten times to get enough data points for the ERP analysis. Here in the current study, more exemplars with a category cue in their Chinese name were added and they came from 11 different categories. And finally, bilinguals were tested in addition to monolinguals. By investigating the effect of labels on categorization in bilinguals, we can gain a better understanding of the language-thought interaction in bilinguals. More specifically, the current study provides some insights into questions such as whether bilinguals show an impact of their L1 when they are doing a categorization task in L2, and whether long-stay bilinguals lose the impact from their L1 when they are doing a categorization task in a pure L2-speaking environment where there are no clues that their L1 is involved.

In Experiment 1, the targets were pictures, as Liu et al.'s studies (2010, 2013). There was no verbal label of the target object present. In Experiment 2, the targets were English words. The object label was presented following the category label. By comparing the effects of category cues in these two categorization tasks, we can gain some insight regarding the question of whether our semantic space is affected by label feedback temporarily or permanently. As was discussed above, there are two explanations about how category information in verbal labels could affect categorization processes. The first explanation is that the activation of the object labels in the categorization task sends feedback to the perceptual level and temporarily influences categorization decision. The second explanation is that one's organization of category representations could be permanently changed under the long-term effects of the everyday usage of object labels. Category members that have category clue in their names are represented closer together in the center of the category, while members without category clue are represented in the periphery of the category, thus influencing categorization decision. It was predicted that in Experiment 1 and Experiment 2, the typicality effect would be smaller for objects with a category cue in their Chinese names than for objects without cues, in response time data as well as in the N300, and N400 ERP components. If it is the case that verbal labels permanently affect the organization of category representations, then we should observe stronger faciliatory effects of category cues in Experiment 2 than in Experiment 1, because in Experiment 2, object labels were presented in the categorization task, so that both of long-term and short-term effects of verbal labels should be operating in Experiment 2, while in Experiment 1, only long-term effects of labels would be operating if names of target pictures were not activated quickly.

In Experiment 1, bilinguals were tested in Chinese and in English. In the Chinese session, they were expected to produce results much like those of Liu et al.'s (2010, 2013) participants, that is, they were expected to show a smaller typicality effect when the objects had a category cue in their Chinese name than when they did not. Of more interest here was whether Chinese-English bilinguals would show the effects of Chinese category cues even when they were tested in English in Experiment 1 and when targets were English words in Experiment 2. Based on the language non-selective activation view of bilingual lexicon activation, bilinguals' two labels for one object should be both activated even when only one language is used. If the feedback from the activation of an object's Chinese name produces a temporary "perceptual warping" of semantic space, the category cue embedded in the Chinese label would make the object's most diagnostic features of the category be activated to a higher degree than non-diagnostic features, especially for atypical exemplars of the category. For example, the feedback from the activation of the Chinese label *鸵鸟* (*ostrich*), which has the category cue *鸟* (*bird*) embedded, would make the diagnostic features of the category bird (e.g., has wings) be activated to a higher degree than if the feedback wasn't available. As a result, atypical objects that have a category cue in their Chinese names would be categorized more easily, thus producing a reduced typicality effect. Alternatively, based on the long-term effects of language view, the organization of category representations would have been changed in bilinguals' minds under the long-term effects of their daily usage of Chinese. Atypical items with a category level cue in their Chinese names should be pulled closer to the centre of the category and to the typical items of the category, making them easier to categorize even when bilinguals are tested in English. Bilinguals were expected to show a weaker effect of category level cue when they were tested in English than when tested in Chinese. The influence of a category level cue on categorization process should be stronger when bilinguals were in a Chinese-speaking environment than when they were in an English-speaking environment, because objects' Chinese labels should be activated more quickly or to a higher degree due to generally raised activation levels of Chinese in a Chinese-speaking environment. Two pilot studies were conducted prior to these experiments to acquire typicality rating and name agreement data for the experimental stimuli.

2.2 Pilot Study 1

Typicality rating data were collected to select typical and atypical items for each category.

2.2.1 Participants

Forty-one English native speakers without any knowledge of Chinese (mean age 19 years, range 18-28, 27 female) and 24 Chinese native speakers (mean age 20 years, range 18-28, 10 female) were recruited via the research participation pool at the University of Western Ontario. Participants received course credit for their participation. Data from seven English speakers and six Chinese speakers were excluded from the analyses due to low quality (they chose a certain rating (e.g., 0 or 100) for a high percentage (greater than 65%) of all items), leaving 34 English speakers and 18 Chinese speakers in the final sample.

2.2.2 Materials and Procedure

A total of 17 categories, and 227 items were selected. Category label and item pairs (e.g., BIRD-robin) were presented to participants one at a time on a computer screen using the Qualtrics platform. All pairs consisted of a category label and a within-category exemplar. No mismatch pairs were presented (e.g., BIRD-desk). Participants were asked to judge whether the item belongs to the category and to rate the typicality of the item using a 0 to 100 slide scale (0-Atypical, 100-Typical). At the end of the session, participants were asked to fill in a questionnaire about their language background and, then, debriefed.

2.2.3 Data Analyses and Results

The mean typicality rating for each item was computed. Based on the averaged typicality rating data from English speakers, 13 categories and 108 items were selected. Half of the items were typical, half of them were atypical. Items with the highest ratings for a category were selected as typical, items with the lowest ratings were selected as atypical. Half of the items had a category label in their Mandarin names, half of them did not. Table 2.1 shows the averaged typicality rating data for each condition, both for the English native speakers and for the Chinese native speakers.

Table 2.1.

Mean Typicality Ratings in Pilot Study 1 (Original set of 108 items)

		Typical	Atypical
English			
	Cue	90.10	66.87
	NoCue	90.29	64.37
Chinese			
	Cue	90.81	82.87
	NoCue	90.41	75.55

The typicality ratings were then analyzed with linear mixed effects (LME) models in R (version 3.4.1, R Development Core Team, 2017) using the lme4 package (version 1.1-18-1, Bates, Mächler, Bolker, & Walker, 2015). A model was fitted with Word Type (Cue vs. NoCue; sum coded), Typicality (Typical vs. Atypical; sum coded), and Language Group (Mandarin vs. English; sum coded) as fixed effects, participants and items as random intercepts, by-participant random slopes for the effects of Word Type and Typicality (with interaction), and by-item random slope for the effect of Language Group. The significance of the fixed effects was determined with effect coding and type-II Wald tests using the Anova function provided by the car package (version 2.1-5; Fox & Weisberg, 2011). Results of the tests evaluating the fixed effects included in the model are presented in Table 2.2.

Table 2.2.

Model for Comparisons of Typicality Ratings in the Potential List of 108 Items

	χ^2	*df*	*p*
Typicality	88.34	1	< .001 ***
Word Type	3.46	1	*ns*
Language Group	0.01	1	*ns*
Typicality x Word Type	4.03	1	.04 *
Typicality x Language Group	19.95	1	< .001 ***
Word Type x Language Group	2.28	1	*ns*
Typicality x Word Type x Language Group	2.04	1	*ns*

As expected, there was a significant main effect of Typicality, typical items were rated with higher scores than atypical items. There was a significant interaction between Typicality and Word Type; the difference between ratings for typical and atypical items was smaller for items with cues than for items without cues. There was also a significant interaction between Typicality and Language Group; the difference between ratings for typical and atypical items was larger in English speakers than in Chinese speakers. Chinese speakers generally gave higher ratings to atypical items than English speakers. This could be due to a cultural inclination by Chinese speakers not to give too low ratings. In addition, the number of Chinese raters (18) in this study was fairly small, and they were a selective group - Chinese-English bilinguals who had immigrated to Canada. These individuals may have given higher ratings than Chinese speakers who lived in China would have given. The three-way interaction between Typicality, Word Type, and Language Group did not reach significance ($p > 0.1$). There was no statistically significant difference in the ratings across language groups regarding the relationship between typicality and word type.

2.3 Pilot Study 2

Name agreement data were then collected for images corresponding to the 108 items chosen in Pilot Study 1. This was done to make sure that image stimuli activated the expected names. The potential set of 13 categories and 108 items in Pilot Study 1 was then further reduced to 11 categories and 84 items after Pilot Study 2.

2.3.1 Participants

Sixty-three English native speakers without any knowledge of Chinese (mean age 22, range 18-29, 34 female) and 46 Chinese native speakers (mean age 19 years, range 17-24, 39 female) were recruited via Amazon Mechanical Turk and the research participation pool at the University of Western Ontario. Participants received course credit or money for their participation. Data from 5 English speakers (they were not born in an English-speaking country, e.g., Germany, India, etc.) were excluded from data analyses, leaving 58 English speakers and 46 Chinese speakers in the final sample.

2.3.2 Procedure

Images of 108 items were selected from the internet, all in colour with a white background. Images were presented to participants one at a time on a computer screen using the Qualtrics platform. Participants were asked to type in a name for each image. At the end of the session, participants were asked to fill in a questionnaire about their language background and then were debriefed.

2.3.3 Data Analyses and Results

Mean name agreement (percentage of expected name) was computed for each item. Synonyms were counted as the same word if they did not cause confusion in categorizing the item as either with a cue or without a cue. For example, the Chinese name for a vest could be either 马甲 or 背心, and neither of them contain the category level cue *clothing*. Items for which fewer than 30% of participants gave the expected name were excluded (with the exception of 4 items, due to the difficulty in getting the same number of items for each condition). The final list consisted of 11 categories and 84 items. Half of the items were typical, half of them were atypical. Half of the items had a category label in their Mandarin names, half of them did not. Seven items had more than one name in Chinese, but all of the names for each item either had a category cue or did not have a category cue. Table 2.3 shows the mean percentage naming agreement for each condition. Table 2.4 shows the mean typicality rating data for each condition for the reduced set of 84 items.

Table 2.3.

Mean Percentage Naming Agreement in Pilot Study 2

		Typical	Atypical
English			
	Cue	76.23	62.36
	NoCue	82.76	74.25
Chinese			
	Cue	83.53	68.58
	NoCue	77.23	73.64

Table 2.4.

Mean Typicality Ratings for the Reduced Set of 84 Items

	Typical	Atypical
English		
Cue	89.69	66.63
NoCue	91.81	65.89
Chinese		
Cue	90.76	82.33
NoCue	91.28	76.25

The typicality ratings from the final stimuli set were then analyzed using an LME model. A model was fitted with Word Type (Cue vs. NoCue; sum coded), Typicality (Typical vs. Atypical; sum coded), and Language Group (Mandarin vs. English; sum coded) as fixed effects, participants and items as random intercepts, by-participant random slopes for the effects of Word Type and Typicality (with interaction), and by-item random slope for the effect of Language Group. Results of the tests evaluating the fixed effects included in the model are presented in Table 2.5.

Table 2.5.

Model for Comparisons of Typicality Ratings in the Final List of 84 Items.

	χ^2	*df*	*p*
Typicality	78.79	1	< .001 ***
Word Type	0.71	1	*ns*
Language Group	0.02	1	*ns*
Typicality x Word Type	3.08	1	*ns*
Typicality x Language Group	16.69	1	< .001 ***
Word Type x Language Group	3.22	1	*ns*
Typicality x Word Type x Language Group	1.12	1	*ns*

As expected, there was a significant main effect of Typicality, typical items were rated with higher scores than atypical items. There was also a significant interaction between Typicality and Language Group; Chinese speakers generally gave higher ratings to atypical items than English speakers. The three-way interaction between Word Type, Typicality and Language Group did not reach significance (p >.20).

To summarize, in Pilot Study 1 and 2, typicality rating data and name agreement data were collected to select experimental stimuli. The potential stimulus list consisted of 13 categories and 108 items, and the final stimulus list consisted of 11 categories and 84 items. Half of the items were typical, half of them were atypical. Half of the items had a category label in their Chinese names, half of them did not. Typical items were rated more highly than atypical items. Importantly, there was no statistically significant difference in the ratings across language groups regarding the relationship between typicality and word type. Chinese speakers generally gave higher ratings to atypical items than English speakers, but this was not moderated by whether their Mandarin name had a category cue.

2.4 Experiment 1

In Experiment 1, I investigated how Chinese word structure affects pictured object categorization in Chinese-English bilinguals. Following in the footsteps of Liu et al.'s studies (2010, 2013), a word-image categorization task was used in Experiment 1. Chinese-English bilinguals were tested in both of their languages. The experiment was conducted in two sessions, and only one language was used in each session. In the Chinese session, bilinguals were expected to produce results similar to those of Liu et al.'s (2010, 2013), that is, they were expected to show a smaller typicality effect when the pictures' Chinese names had a category cue than when they did not. Of more interest here was whether Chinese-English bilinguals would also show an effect of these Chinese category cues even when they were tested in English.

There is ample evidence showing that the context in which language use occurs moderates the level of activation of bilingual's two languages. For example, bilinguals named pictures faster when the language of the task matched the cultural bias of the picture (Jared, Poh, & Paivio, 2013) and participants made faster responses on a picture-word matching task when the cultural bias of the picture matched the language in which the word was presented (Berkes, Friesen, & Bialystok, 2018). Additionally, many studies have shown that bilingual's L2 fluency can be disrupted by exposure to visual cues of L1 culture, such as a face from the L1 culture (Hartsuiker, 2015; Woumans et al., 2015; Zhang, Morris, Cheng, & Yap, 2013). Therefore, in the present experiment, the testing environment was designed to match the language of the session, so that the testing language should be at a higher activation level in the bilingual's mind than the other language. Participants were greeted in English by a monolingual Caucasian research assistant for the English session, and all conversation and consent forms were in English. Similarly, in the Chinese session, participants were greeted in Chinese by an Asian native Chinese speaker and all conversation and forms were in Chinese.

2.4.1 Method

2.4.1.1 Participants

Thirty-four Chinese-English bilinguals (mean age 19, range 18-29, 25 female) and 28 English monolinguals (mean age 19, range 18-22, 20 female) were recruited via the research participation pool at the University of Western Ontario and advertisements on WeChat groups (a popular social media app among Chinese students). Participants received course credit or money for their participation. Data from six bilinguals were excluded from analyses (three of them were native speakers of Cantonese but not Mandarin, two of them did not complete the whole session, one had poor ERP data recording), leaving 28 Chinese-English bilinguals and 28 English monolinguals in the final sample. The first language of all bilinguals in the final sample was Mandarin. All bilinguals were born in China (including Taiwan), had lived in China for a mean duration of 16.02 years (range 9-25), and had lived in Canada for a mean duration of 4.89 years (range 2-9). The bilinguals rated their English language skills on a scale of 1 (none) to 10 (native-like fluency); the means were 7.35 for spoken comprehension, 7.19 for reading, 6.27 for speaking, and 6.77 for writing. The bilinguals also self-reported the percentage of time that they currently exposed to each of their language in their daily activities. The bilinguals were exposed to English for a mean of 45% of the time, and they were exposed to Mandarin Chinese for a mean of 51% of the time.

2.4.1.2 Materials

Critical stimuli for this study were the 84 category label-object image pairs normed in Pilot Study 1 and 2. Half of the objects were typical, half of them were atypical (See Table 2.3 for mean typicality ratings). Half of the objects had a category label in their Mandarin names, half of them did not (see Appendix A for the list of stimuli).

2.4.1.3 Procedure

A category label-image matching task was used (see Figure 2.1). Participants first saw a 500 ms fixation cross, followed by a category label (e.g., *BIRD* in English; 鸟 in Mandarin) for 500 ms, then followed by an image of an object (e.g., *robin*). Participants were instructed to judge whether or not the image was an example of the concept represented by the first word. All word-image pairs were presented twice to each participant in a random order in order to get clear ERP signal after averaging. A total of 348 trials were presented, including 168 critical trials that required a *yes* response (42 trials per condition), 168 filler trials that required a *no* response, and 12 practice trials. Filler trials were created by re-pairing the category label-image pairs from critical trials. This means that each target picture was presented four times to each participant: two requiring a *yes* response, and two requiring a *no* response. English monolinguals were tested only in English. Chinese-English bilinguals were tested in both Chinese and English in two separate sessions. The second session was conducted at least 7 days after the first session; half of the participants did the Chinese session first, and half of them did English session first. As mentioned previously, the testing environment matched the language of the session, with the Chinese sessions conducted exclusively in Chinese by a native speaker of Chinese and English sessions conducted exclusively in English by a native Canadian. At the end of the second session, participants were asked to fill in a questionnaire about their language background and, then, debriefed.

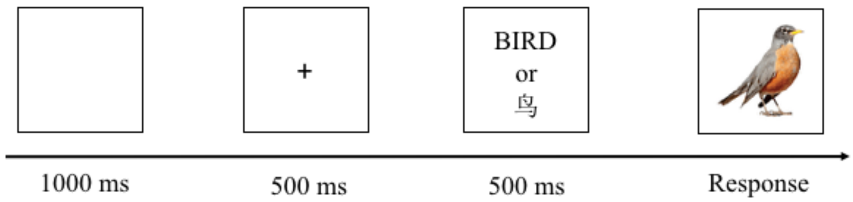

Figure 2.1. Experimental procedure in Experiment 1.

2.4.1.4 EEG Recording and Preprocessing

Continuous EEG activity was recorded at 32 scalp sites using ActiveTwo BioSemi active Ag/AgCl electrodes embedded in a custom elastic cap (BioSemi, Amsterdam, The Netherlands). The electro-oculogram (EOG) was recorded with electrodes placed above and below the right eye (vertical), and on the outer canthus of each eye (horizontal). Data were recorded using ActiView software (BioSemi) in the frequency range of 0.1-100 Hz at a sampling rate of 512 Hz. All EEG electrode impedances were maintained below 5 kΩ.

Off-line analysis was performed using ERPlab toolbox (Lopez-Calderon & Luck, 2014). All data were re-referenced to the mean electrical activity of the mastoids and bandpass filtered with cutoffs of 0.1 and 30 Hz. The epochs of interest for target images were established to be from -200 to 800 ms post-stimulus onset. Data were baseline corrected to the prestimulus baseline. The data were filtered of eye-movement artifacts that were identified by running an independent component analysis (ICA). Trials contaminated with activity greater than ±75 microvolts (μΩ) were excluded from the analysis (8.88% of the trials were excluded for bilinguals in the English session, 9.24% of the trials were excluded for bilinguals in the Chinese session, and 10.71 % of the trials were excluded for English monolinguals).

2.4.2 Results

2.4.2.1 Behavioural Analyses

Incorrect responses (5.42% for the bilingual's English session, 3.59% for the bilingual's Chinese session, and 4.99% for the English monolinguals), as well as response times that were shorter than 200 ms or longer than 1500 ms (2.46% for the bilingual's English session, 1.29% for bilingual's Chinese session, 0.93% for the English monolinguals) were excluded from the analyses of the latency data for critical trials. Table 2.6 shows the mean response times and error rates for all critical trials, the first exposure (participants saw the item for the first time), and the second exposure. Only reaction times (RTs) were analyzed in the behavioural analyses, because error rates were pretty low in both bilingual and English monolingual groups (generally under 5%). Two sets of analyses were conducted. The first set included only data from the bilinguals and included Test Language as a variable. The second set included only data from the English sessions and included Language Group as a variable. Of interest were whether there was an overall main effect of Typicality, whether the size of the typicality effect (RTs for atypical items minus typical items) depends on whether words have a category cue in their name (a Typicality x Word Type interaction), and whether this interaction is impacted either by the language of the task for bilinguals (a triple interaction of Typicality x Word Type x Test Language) or the language group for the English sessions (a triple interaction of Typicality x Word Type x Language Group).

Table 2.6.

Mean Response Times (in ms) and Percentage Error Rates (between brackets) in Experiment 1.

	All trials					
	Cue			NoCue		
	Typical	Atypical	Typicality effect	Typical	Atypical	Typicality effect
Bilingual						
Chinese session	539 (2.21)	559 (3.82)	20 (1.61)	542 (2.80)	591 (5.52)	49 (2.72)
English session	547 (3.65)	573 (6.20)	26 (2.55)	549 (3.99)	584 (7.82)	35 (3.82)
English monolingual	499 (2.80)	527 (5.10)	28 (2.29)	494 (3.14)	526 (8.92)	32 (5.78)
	First exposure					
	Cue			NoCue		
	Typical	Atypical	Typicality effect	Typical	Atypical	Typicality effect
Bilingual						
Chinese session	542 (2.55)	559 (4.42)	17 (1.87)	544 (2.89)	599 (4.59)	55 (1.70)
English session	553 (3.57)	574 (6.80)	21 (3.23)	547 (4.42)	600 (7.82)	53 (3.40)
English monolingual	499 (3.74)	541 (5.27)	42 (1.53)	503 (3.23)	538 (10.03)	35 (6.80)
	Second exposure					
	Cue			NoCue		
	Typical	Atypical	Typicality effect	Typical	Atypical	Typicality effect
Bilingual						
Chinese session	536 (1.87)	560 (3.23)	24 (1.36)	540 (2.72)	582 (6.46)	42 (4.40)
English session	540 (3.74)	571 (5.61)	31 (1.87)	550 (3.57)	568 (7.82)	18 (4.25)
English monolingual	499 (1.87)	514 (4.93)	15 (3.06)	485 (3.06)	514 (7.82)	29 (4.76)

In the first set of analyses, RTs from the two sessions that were completed by bilinguals were analyzed with linear mixed effects (LME) models in R (version 3.4.1, R Development Core Team, 2017) using the lme4 package (version 1.1-18-1, Bates, Mächler, Bolker, & Walker, 2015). Model 1 was fitted with Typicality (Typical vs. Atypical, sum coded), Word Type (Cue vs. NoCue, sum coded), Test Language (Chinese vs. English, sum coded), and Exposure Order (First Exposure vs. Second Exposure, sum coded) as fixed effects, participants and items as random intercepts, and by-participant random slopes for the effects of Typicality, Word Type, and Test Language (without interactions). The significance of the fixed effects was determined with effect coding and type-II Wald tests using the Anova function provided by the car package (version 2.1-5; Fox & Weisberg, 2011). Further analyses with LME models used the same methods and R packages. Results of the tests evaluating the fixed effects included in Model 1 are presented in Table 2.7.

Table 2.7.

Analysis of Variance Table for Model 1 (RTs in the two sessions that were completed by bilinguals).

	χ^2	*df*	*p*
Typicality	12.17	1	< .001 ***
Word Type	1.55	1	*ns*
Test Language	0.47	1	*ns*
Exposure Order	5.22	1	.02 *
Typicality x Word Type	1.16	1	*ns*
Typicality x Test Language	0.21	1	*ns*
Typicality x Exposure Order	0.66	1	*ns*
Word Type x Test Language	1.88	1	*ns*
Word Type x Exposure Order	0.70	1	*ns*
Test Language x Exposure Order	0.34	1	*ns*
Typicality x Word Type x Test Language	1.40	1	*ns*
Typicality x Word Type x Exposure Order	4.36	1	.03 *
Typicality x Test Language x Exposure Order	0.61	1	*ns*
Word Type x Test Language x Exposure Order	0.00	1	*ns*
Typicality x Word Type x Test Language x Exposure Order	0.94	1	*ns*

There was a significant main effect of Typicality and a significant main effect of Exposure Order. Typical items were responded to 32 ms faster than atypical items. Items were responded to 9 ms faster when they were exposed to participants for the second time than the first time. The key interaction between Word Type and Typicality did not reach significance (*p* > .20), but there was a significant three-way interaction between Typicality, Word Type, and Exposure Order (*p* = .03), suggesting that the relationship between Word Type and Typicality could be different for the first exposure and the second exposure. Therefore, I further analyzed data from the first and second exposure separately.

RTs from the first and the second exposure were fitted in Model 2 and Model 3 separately with Typicality (Typical vs. Atypical, sum coded), Word Type (Cue vs. NoCue, sum coded), and Test Language (Chinese vs. English, sum coded) as fixed effects, participants and items as random intercepts, and by-participant random slopes for the effects of Typicality and Word Type (without interaction). Results of the tests evaluating the fixed effects included in the models are presented in Table 2.8 and Table 2.9.

Table 2.8.

Analysis of Variance Table for Model 2 (RTs from the first exposure in the two sessions that were completed by bilinguals).

	χ^2	*df*	*p*
Typicality	10.61	1	< .001 ***
Word Type	1.84	1	*ns*
Test Language	2.44	1	*ns*
Typicality x Word Type	2.66	1	.10
Typicality x Test Language	0.06	1	*ns*
Word Type x Test Language	0.82	1	*ns*
Typicality x Word Type x Test Language	0.04	1	*ns*

Table 2.9.

Analysis of Variance Table for Model 3 (RTs from the second exposure in the two sessions that were completed by bilinguals).

	χ^2	*df*	*p*
Typicality	10.57	1	< .001 ***
Word Type	0.88	1	*ns*
Test Language	0.47	1	*ns*
Typicality x Word Type	0.02	1	*ns*
Typicality x Test Language	0.74	1	*ns*
Word Type x Test Language	0.94	1	*ns*
Typicality x Word Type x Test Language	2.15	1	*ns*

In the analysis of the first exposure (Model 2), there was a significant main effect of Typicality. Typical items were responded to 36 ms faster than atypical items. There is a trend for the interaction between Typicality and Word Type ($p = .10$). The typicality effect (RTs for atypical items minus typical items) was 35 ms smaller for items with cues (19 ms) than items without cues (54 ms). The three-way interaction between Typicality, Word Type, and Test Language was not significant ($p > .80$), indicating that Chinese-English bilinguals showed the same response pattern regardless of the language used in testing. In the analysis of the second exposure (Model 3), there was a significant main effect of Typicality. Typical items were responded to 28 ms faster than atypical items. However, no interaction between Typicality and Word Type was found ($p > .80$).

In the second sets of analyses, RTs from the English sessions were analyzed with LME models. Model 4 was fitted with Typicality (Typical vs. Atypical, sum coded), Word Type (Cue vs. NoCue, sum coded), Language Group (Bilingual vs. English Monolingual, sum coded), and Exposure Order (First Exposure vs. Second Exposure, sum coded) as fixed effects, participants and items as random intercepts, and by-participant random slopes for the effects of Typicality and Word Type (without interaction). Results of the tests evaluating the fixed effects included in Model 4 are presented in Table 2.10.

Table 2.10.

Analysis of Variance Table for Model 4 (RTs in the English sessions).

	χ^2	*df*	*p*
Typicality	10.53	1	.001 **
Word Type	0.03	1	*ns*
Language Group	4.92	1	.02 ***
Exposure Order	16.47	1	< .001 ***
Typicality x Word Type	0.15	1	*ns*
Typicality x Language Group	0.01	1	*ns*
Typicality x Exposure Order	4.93	1	.02 *
Word Type x Language Group	1.44	1	*ns*
Word Type x Exposure Order	1.18	1	*ns*
Language Group x Exposure Order	0.88	1	*ns*
Typicality x Word Type x Language Group	0.13	1	*ns*
Typicality x Word Type x Exposure Order	0.93	1	*ns*
Typicality x Language Group x Exposure Order	0.22	1	*ns*
Word Type x Language Group x Exposure Order	0.00	1	*ns*
Typicality x Word Type x Language Group x Exposure Order	5.40	1	.02 *

There was a significant main effect of Typicality, a significant main effect of Language Group, and a significant main effect of Exposure Order. Typical items were responded to 30 ms faster than atypical items. English monolinguals responded 52 ms faster than bilinguals. Items were responded to 14 ms faster when they were exposed to participants for the second time than the first time. The key three-way interaction between Typicality, Word Type, and Language Group did not reach significance ($p > .70$). However, there was a significant four-way interaction between Typicality, Word Type, Language Group, and Exposure Order ($p = .02$), suggesting that the relationship between Word Type, Typicality and Language Group could be different for the first exposure and the second exposure. Therefore, I further analyzed data from the first and second exposure separately.

RTs from the first and the second exposure were fitted in Model 5 and Model 6 separately with Typicality (Typical vs. Atypical, sum coded), Word Type (Cue vs. NoCue, sum coded), and Language Group (Bilingual vs. English Monolingual, sum coded) as fixed effects, participants and items as random intercepts, and by-participant random slopes for the effects of Typicality and Word Type (without interaction). Results of the tests evaluating the fixed effects included in the models are presented in Table 2.11 and Table 2.12.

Table 2.11.

Analysis of Variance Table for Model 5 (RTs from the first exposure in the English sessions).

	χ^2	*df*	*p*
Typicality	10.71	1	.001 **
Word Type	0.24	1	*ns*
Language Group	3.66	1	.05 *
Typicality x Word Type	0.40	1	*ns*
Typicality x Language Group	0.13	1	*ns*
Word Type x Language Group	0.63	1	*ns*
Typicality x Word Type x Language Group	3.72	1	.05 *

Table 2.12.

Analysis of Variance Table for Model 6 (RTs from the second exposure in the English sessions).

	χ^2	*df*	*p*
Typicality	7.03	1	.008 **
Word Type	0.06	1	*ns*
Language Group	6.27	1	.01 *
Typicality x Word Type	0.00	1	*ns*
Typicality x Language Group	0.07	1	*ns*
Word Type x Language Group	0.87	1	*ns*
Typicality x Word Type x Language Group	1.96	1	*ns*

In the analysis of the first exposure (Model 5), there was a significant main effect of Typicality, and a significant main effect of Language Group. Typical items were responded to 38 ms faster than atypical items. English monolinguals responded 48 ms faster than bilinguals. Importantly, there was a significant three-way interaction among Word Type, Typicality, and Language Group (p = .05), suggesting that the relationship between Typicality and Word Type differed in bilinguals and English monolinguals. To probe the triple interaction further, data for English monolinguals and bilinguals were analyzed with LME models separately. Models were fitted with Typicality (Typical vs. Atypical, sum coded) and Word Type (Cue vs. NoCue, sum coded) as fixed effects, and participants and items as random intercepts. Results showed that for English monolinguals, there was a significant main effect of Typicality, $\chi^2(1) = 11.88$, $p < .001$, but no significant Typicality x Word Type interaction, $\chi^2(1) = .02$. The typicality effect was similar for items with cues (42 ms) and items without cues (35 ms) in English monolinguals. For Chinese-English bilinguals, there was a significant main effect of Typicality, $\chi^2(1) = 6.82$, $p = .009$, and a weak trend for the Typicality x Word Type interaction, $\chi^2(1) = 1.56$, $p = .21$. The typicality effect was 32 ms smaller for items with cues (21 ms) than items without cues (53 ms) in bilinguals.

Likelihood ratio tests were conducted to measure the effect size of the three-way interaction among Word Type, Typicality, and Language Group (p = .05). Specifically, the relative likelihood was computed by comparing the Akaike information criteria (AIC; Akaike, 1973, 1974) of two models: the full model with the triple interaction and the reduced model without the interaction using the formula: exp((AIC(model.reduced) – AIC(model.full))/2) (Burnham & Anderson, 1998, 2004). The relative likelihood indicates the likelihood that each model would minimize information loss compared to the other model. Here a relative likelihood of 2.36 was found, indicating that the full model with triple interaction was 2.36 times more likely than the reduced model without triple interaction to minimize information loss. In the analysis of the second exposure (Model 6), there was a significant main effect of Typicality, and a significant main effect of Language Group. Typical items were responded to 23 ms faster than atypical items. English monolinguals responded 54 ms faster than bilinguals. However, no significant three-way interaction between Typicality, Word Type, and Language Group was found (*p* > .15).

To sum up the behavioral results, the effects of interest were generally found in the first exposure data. An overall main effect of Typicality was found in the two sets of analyses. Both bilinguals and English monolinguals categorized typical items more easily than atypical items. The typicality effect in bilinguals was found to depend on whether words have a category cue in their Chinese name (a Typicality x Word Type interaction); the typicality effect was smaller for items with cues than items without cues. Importantly, the same pattern of results was observed in bilinguals' two languages; no significant Typicality x Word Type x Test Language interaction was found. Furthermore, in the analysis of English sessions, bilinguals and English monolinguals showed different response patterns; a significant triple interaction of Typicality x Word Type x Language Group was found. In contrast to the pattern just described for bilinguals, English monolinguals produced similar-sized typicality effects for items with cues and items without cues in their Chinese name. Repeating items a second time attenuated critical findings.

2.4.2.2 ERP Analyses

The data from 22 electrodes (F3, Fz, F4, FC5, FC1, FC2, FC6, C3, Cz, C4, CP5, CP1, CP2, CP6, P3, Pz, P4, PO3, PO4, O1, Oz, O2) were included in the analyses. For each participant, the data from 22 electrodes were averaged for each condition. Peripheral electrodes (Fp1, Fp2, AF3, AF4, F7, F8, T7, T8, P7, P8) were excluded from data analyses due to low signal-noise ratio (see Figure 2.2). The negative going N300 component peaked at about 325 ms and was measured in the 250-350 ms time window. In addition to the N300, an extended late component (ELC) was measured in the 400-500 ms time window. Figures 2.3, 2.4, and 2.5. show the grand average waveforms in microvolts (μV) evoked in response to the four conditions and voltage maps showing the typicality effect on N300 and ELC components for the bilingual Mandarin session, the bilingual English session, English monolinguals, respectively. As was done for the behavioral data, one set of analyses was done on the data from bilinguals (English and

Chinese sessions) and one set of analyses was done on the English data (bilingual and monolingual participants). Analyses were done only on data from both presentations of the pictures. The coding of the ERP component of the experiment did not permit the separation of data from the first and second presentation.

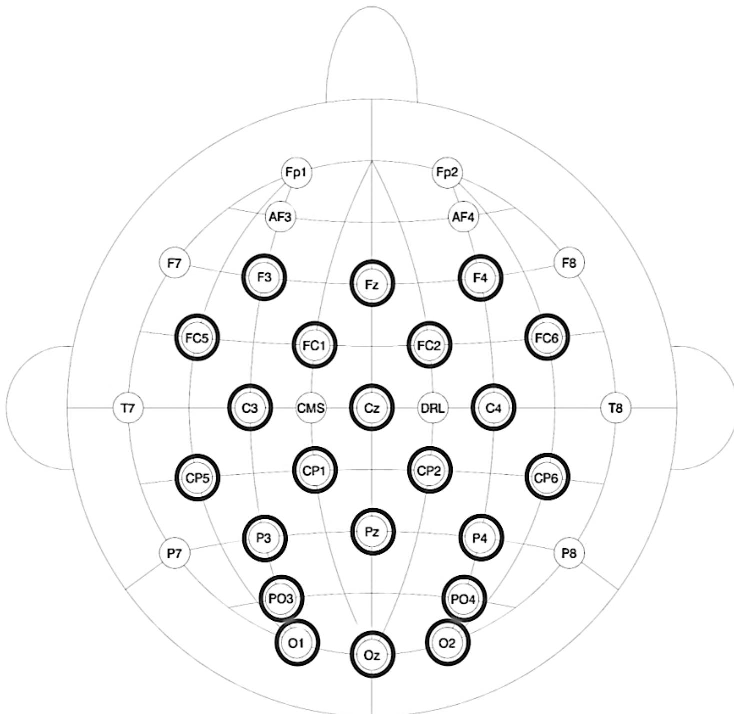

Figure 2.2. Electrode montage for Experiment 1 and Experiment 2. Circles indicate electrodes included in the analysis.

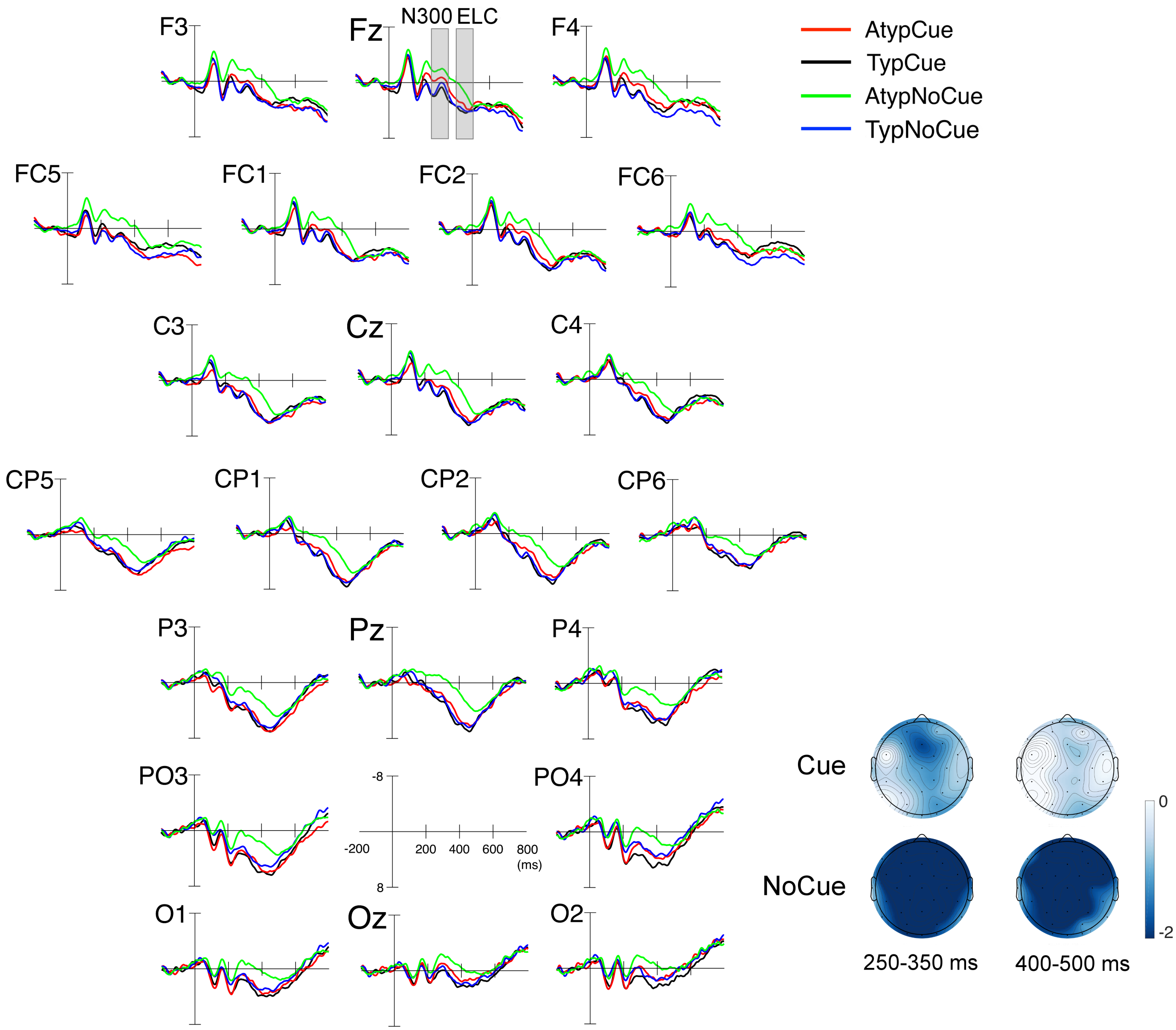

Figure 2.3. Grand average waveforms in microvolts (µV) and voltage maps of the typicality effect (Atypical - Typical) in N300 and ELC components for bilinguals in the Chinese session in Experiment 1.

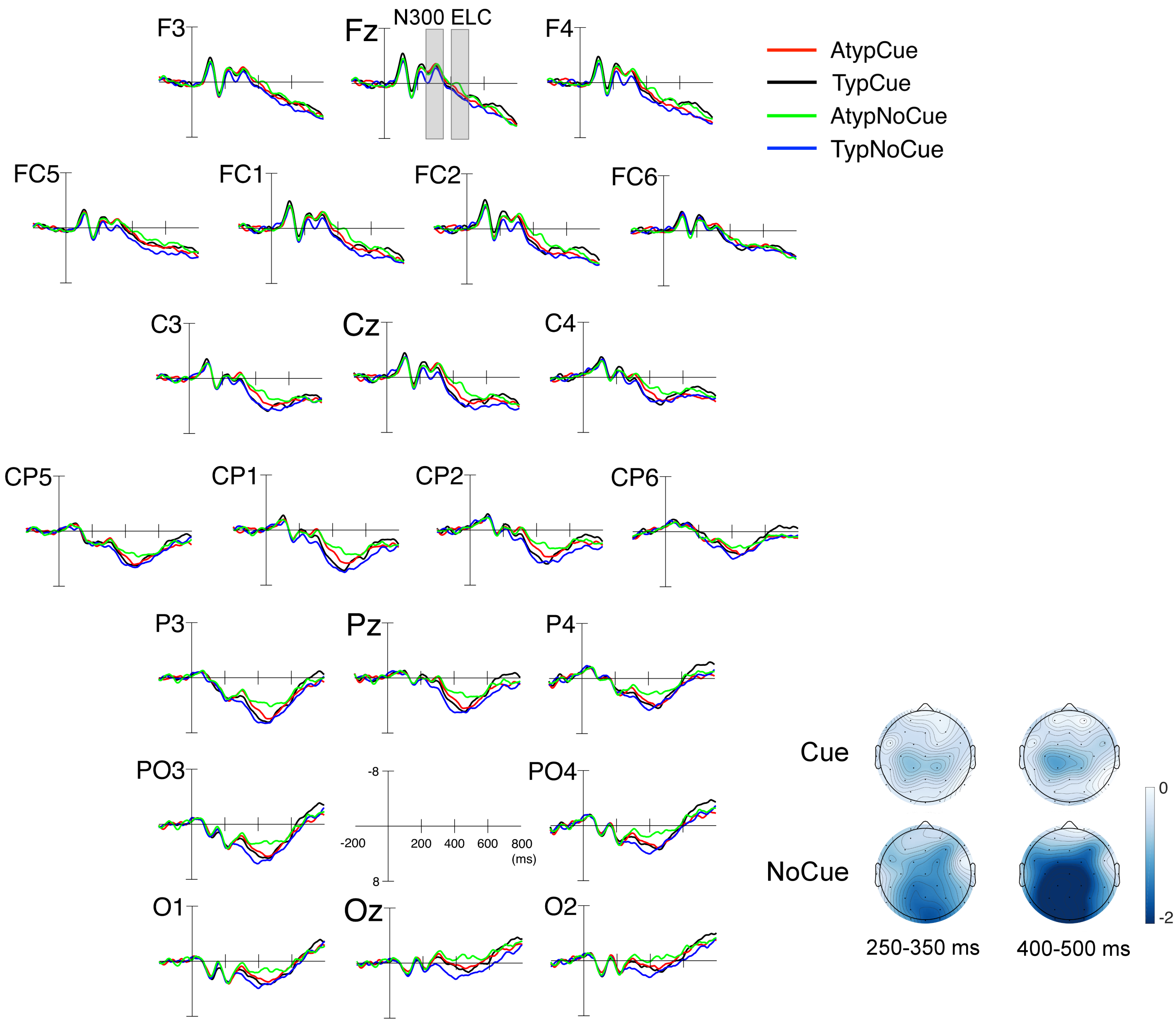

Figure 2.4. Grand average waveforms in microvolts (μV) and voltage maps of the typicality effect (Atypical - Typical) in N300 and ELC components for bilinguals in the English session in Experiment 1.

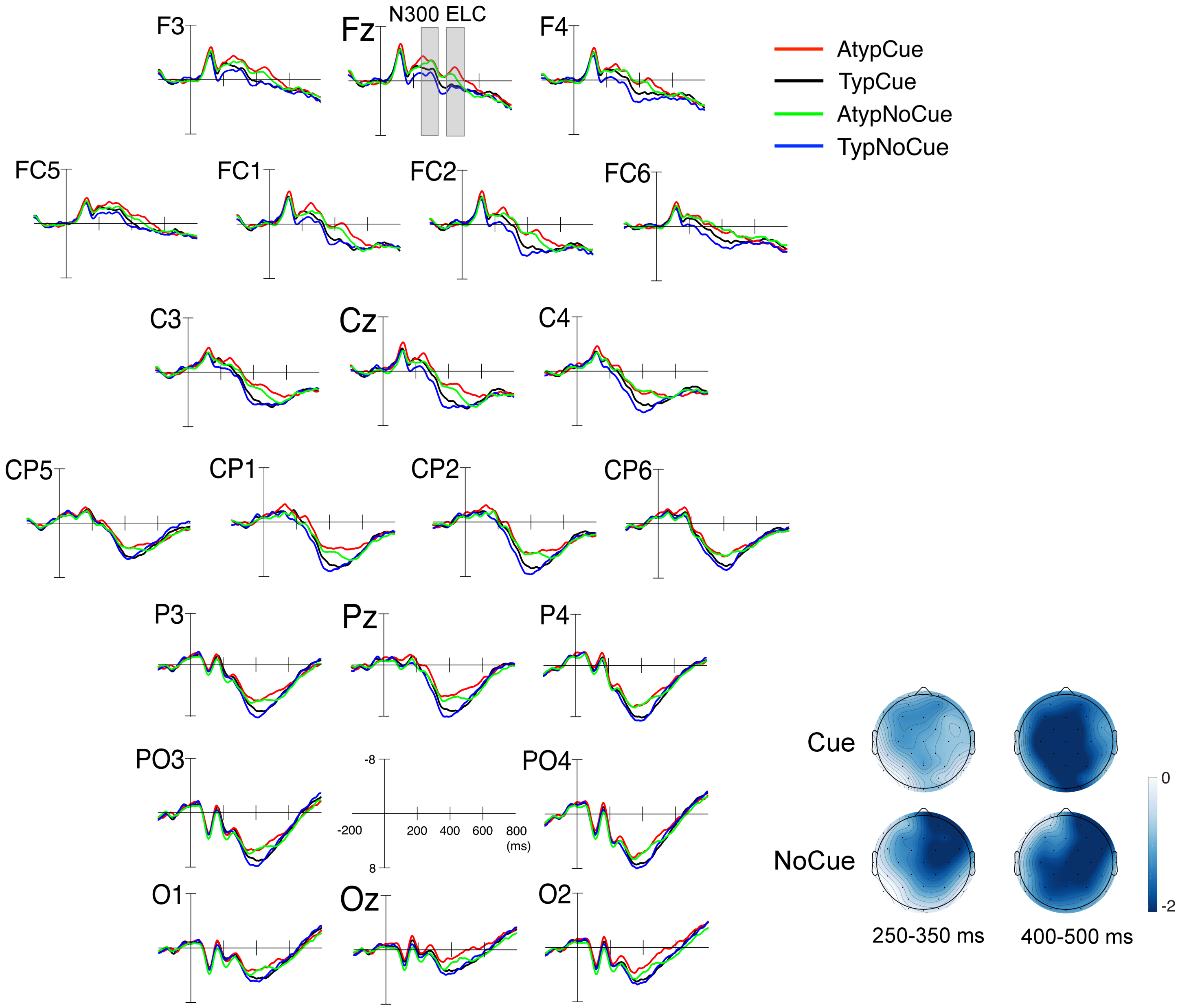

Figure 2.5. Grand average waveforms in microvolts (μV) and voltage maps of the typicality effect (Atypical - Typical) in N300 and ELC components for the English monolinguals in Experiment 1.

N300 (250-350 ms)

In the first set of analyses, mean amplitudes in the 250 ms to 350 ms time window from the two sessions that were completed by bilinguals were analyzed with LME models. Model 7 was fitted with Typicality (Typical vs. Atypical, sum coded), Word Type (Cue vs. NoCue, sum coded), and Test Language (Chinese vs. English, sum coded) as fixed effects, participants as random intercept, and by-participant random slopes for the effects of Typicality, Word Type, and Test Language (without interactions). Results of the tests evaluating the fixed effects included in the model are presented in Table 2.13.

Table 2.13.

Analysis of Variance Table for Model 7 (N300 mean amplitudes in the two sessions that were completed by bilinguals).

	χ^2	*df*	*p*
Typicality	16.56	1	< .001 ***
Word Type	2.47	1	*ns*
Test Language	3.01	1	.08
Typicality x Word Type	5.96	1	.01 *
Typicality x Test Language	3.81	1	.05 *
Word Type x Test Language	9.75	1	.001 **
Typicality x Word Type x Test Language	0.74	1	*ns*

There was a significant main effect of Typicality ($p < .001$). Atypical items elicited a more negative N300 than typical items. Importantly, there was a significant interaction between Typicality and Word Type ($p = .01$). The typicality effect was significantly smaller for items with cues than items without cues. The three-way interaction between Typicality, Word Type, and Test Language was not significant ($p > .30$). Chinese-English bilinguals showed the same response pattern regardless of the language used in testing. Indeed, separate models for each test language confirmed that the Typicality x Word Type interaction was significant for bilinguals in both the Chinese, $\chi^2(1) = 4.09$, $p = .04$, and English test sessions, $\chi^2(1) = 5.31$, $p = .02$.

In the second set of analyses, mean amplitudes in the 250 ms to 350 ms time window from the English sessions were analyzed with LME models. Model 8 was fitted with Typicality (Typical vs. Atypical, sum coded), Word Type (Cue vs. No Cue, sum coded), and Language Group (Bilingual vs. English Monolingual, sum coded) as fixed effects, participants as random intercept, and by-participant random slopes for the effects of Typicality and Word Type (without interaction). Results of the tests evaluating the fixed effects included in the model are presented in Table 2.14.

Table 2.14.

Analysis of Variance Table for Model 8 (N300 mean amplitudes in the English sessions).

	χ^2	*df*	*p*
Typicality	23.33	1	< .001 ***
Word Type	4.57	1	.03 *
Language Group	3.21	1	.07
Typicality x Word Type	2.77	1	.09
Typicality x Language Group	0.35	1	*ns*
Word Type x Language Group	0.58	1	*ns*
Typicality x Word Type x Language Group	0.47	1	*ns*

There was a significant main effect of Typicality ($p < .001$), and a significant main effect of Word Type ($p = .03$). Atypical items elicited a more negative N300 than typical items; items without cues elicited a more negative N300 than items with cues. The three-way interaction between Typicality, Word Type, and Language Group did not reach significance ($p > .40$). However, separate models for each language group revealed that the Typicality x Word Type interaction was significant for bilinguals, $\chi^2(1) = 5.31$, $p = .02$, as previously noted, but not for monolinguals, $\chi^2(1) = 0.34$. At this early time point, although different patterns are beginning to arise for bilinguals and monolinguals, there appears to have been too much variability across participants and electrodes to produce a significant triple interaction.

ELC (400-500 ms)

In the first set of analyses, mean amplitudes in the 400 ms to 500 ms time window from the two sessions that were completed by bilinguals were analyzed with LME models. Model 9 was fitted with Typicality (Typical vs. Atypical, sum coded), Word Type (Cue vs. NoCue, sum coded), and Test Language (Chinese vs. English, sum coded) as fixed effects, participants as random intercept, and by-participant random slopes for the effects of Typicality, Word Type, and Test Language (without interactions). Results of the tests evaluating the fixed effects included in the model are presented in Table 2.15.

Table 2.15.

Analysis of Variance Table for Model 9 (ELC mean amplitudes in the two sessions that were completed by bilinguals).

	χ^2	*df*	*p*
Typicality	23.43	1	< .001 ***
Word Type	9.66	1	.001 **
Test Language	5.64	1	.01 *
Typicality x Word Type	12.50	1	< .001 ***
Typicality x Test Language	0.03	1	*ns*
Word Type x Test Language	1.92	1	*ns*
Typicality x Word Type x Test Language	0.35	1	*ns*

There was a significant main effect of Typicality ($p < .001$), a significant main effect of Word Type ($p = .001$), and a significant main effect of Test language ($p = .01$). Atypical items elicited a more negative ELC than typical items; items without cues elicited a more negative ELC than items with cues; a more negative ELC was elicited when bilinguals were tested in English than in Chinese. Importantly, there was a significant interaction between Typicality and Word Type ($p < .001$). The typicality effect was significantly smaller for items with cues than items without cues. The three-way interaction between Typicality, Word Type, and Test Language was not significant ($p > .40$). Chinese-English bilinguals showed the same response pattern regardless of the language used in testing. Separate models for each test language confirmed that the Typicality x Word Type interaction was significant for bilinguals in both the Chinese, $\chi^2(1) = 9.26$, $p = .002$, and English test sessions, $\chi^2(1) = 5.59$, $p = .01$.

In the second set of analyses, mean amplitudes in the 400 ms to 500 ms time window from the English sessions were analyzed with LME models. Model 10 was fitted with Typicality (Typical vs. Atypical, sum coded), Word Type (Cue vs. NoCue, sum coded), and Language Group (Bilingual vs. English Monolingual, sum coded) as fixed effects, participants as random intercept, and by-participant random slopes for the effects of Typicality and Word Type (without interaction). Results of the tests evaluating the fixed effects included in the model are presented in Table 2.16.

Table 2.16.

Analysis of Variance Table for Model 10 (ELC mean amplitudes in the English sessions).

	χ^2	*df*	*p*
Typicality	48.11	1	< .001 ***
Word Type	0.07	1	*ns*
Language Group	3.56	1	.05 *
Typicality x Word Type	2.90	1	.08
Typicality x Language Group	1.88	1	*ns*
Word Type x Language Group	3.58	1	.05 *
Typicality x Word Type x Language Group	3.08	1	.07

There was a significant main effect of Typicality ($p < .001$). Atypical items elicited a more negative ELC than typical items. Importantly, the three-way interaction between Typicality, Word Type, and Language Group approached significance ($p = .07$). Separate analyses on each language group revealed that the Typicality x Word Type interaction was significant for bilinguals, $\chi^2(1) = 5.59$, $p = .01$, but not for monolinguals, $\chi^2(1) = 0.001$. The typicality effects were smaller for items with cues than items without cues in bilinguals but were similar for items with cues and items without cues in English monolinguals. Likelihood ratio tests were conducted to measure the effect size of the three-way interaction. AIC of the full model with the triple interaction and the reduced model without the interaction was compared. A relative likelihood of 2.36 was found, indicating that the full model was 2.36 times more likely than the reduced model to minimize information loss.

To sum up the ERP results, in the analyses of Chinese and English sessions that were completed by bilinguals, a significant interaction between Typicality and Word Type was found in both N300 and ELC components. The typicality effect was smaller for items with cues than items without cues. Importantly, the same pattern of results was observed in both languages. Specifically, bilinguals categorized items with cues more easily than items without cues, especially for the atypical items, even when they were doing the task in English and were put into an English-speaking environment. In the analyses of English sessions, the triple interaction between Word Type, Typicality, and Language Group was not yet evident in the N300 data, but it did approach significance in subsequent time window (ELC). The English monolinguals did not produce in either component the significant interaction between Typicality and Word Type that was seen in bilinguals. These ERP results are consistent with the behavioural data from the first exposure.

2.4.3 Discussion

In Experiment 1, I examined the effects of Chinese word structure on bilinguals' categorization processes with pictorial stimuli. Response times and brain responses were measured as Chinese-English bilinguals and English monolinguals categorized images of typical and atypical objects. The typicality effect (atypical items were categorized with more difficulty) was reflected in response times, N300 and ELC ERP components. Both behavioural and ERP results showed that the typicality effect was smaller for items with cues in their Chinese names than items without cues in bilinguals, while English monolinguals showed no such difference, as expected, because the category information in objects' Chinese names is not available to them. The difference in findings for bilingual and monolingual participants means that the results for bilinguals can be more confidently attributed to their knowledge of Chinese. In addition, the facilitation from objects' Chinese names in bilinguals existed regardless of the language used for testing. That is, category information in an object's Chinese name facilitated bilinguals' categorization of the object no matter whether they were tested in a Chinese-speaking or English-speaking environment.

In the behavioural response time data, atypical items were responded to more slowly than typical items in both Chinese-English bilinguals and English monolinguals, which is consistent with previous studies investigating the typicality effect (e.g., Casey, 1992; Mervis & Rosch, 1981). Both bilinguals and English monolinguals had more difficulty categorizing atypical items than typical items. When comparing RTs from the two sessions that were completed by bilinguals, the typicality effect was marginally smaller for items with cues than items without cues, but only in the first exposure data. When comparing RTs from the two English sessions, the typicality effect was smaller for items with cues than items without cues in bilinguals, while English monolinguals showed no such difference. These differences observed between bilinguals and English monolinguals only existed in the first exposure data. These findings suggest that even when categorizing pictures, information embedded in verbal labels influences bilinguals' categorization processes. The category information imbedded in objects' Chinese names facilitated bilinguals' categorization and reduced the influence of typicality, resulting in bilinguals categorizing atypical items with cues more easily than those without cues. In addition, RTs from the first exposure data and the second exposure data showed different patterns. Overall, both bilinguals and English monolinguals responded faster when items were exposed to them for the second time than the first time, especially for atypical items. The faciliatory effects from category information in objects' Chinese names only appeared in the first exposure data. This could be due to the familiarity effect: as participants became more familiar with the experimental stimuli, they made faster responses, especially for atypical items, thus the typicality effects diminished in the second exposure data.

In the ERP data, atypical items elicited a more negative N300 and ELC than typical items in both Chinese-English bilinguals and English monolinguals, consistent with Liu et al.'s study (2010) and several previous studies investigating the typicality effect with ERPs (Hauk et al., 2007; West & Holcomb, 2002). Bilinguals showed a smaller typicality effect in the N300 and ELC components for items with cues in their Chinese names than items without cues in both the Chinese session and the English session. On the other hand, English monolinguals showed a similar typicality effect in the N300 and ELC components for items with cues and items without cues. In previous studies, the negative going N300 component has been found to be related to how integral the meaning of a non-verbal stimulus (e.g., picture, video) is to the whole context, which highly resembles the categorization process (Sitnikova, Kuperberg, & Holcomb, 2003; West & Holcomb, 2002). The categorization process can be described as making judgments on how integral the meaning of a category member is to the category as a whole. In addition, the extended late occurring component (ELC) has also been found to be involved in the typicality effect with non-verbal stimuli (Liu et al., 2010; West & Holcomb, 2002; the time window for the ELC varies in different studies from 400 ms to 700 ms). Researchers have suggested that the ELC might indicate different levels of decision making and evaluative processes (Heinze, Muente, & Kutas, 1998; Stuss, Picton, & Cerri, 1988) or violations of rules or goal-related requirements (Sitnikova, Holcomb, Kiyonaga, & Kuperberg, 2008; Sitnikova et al., 2003). Therefore, findings in the current study indicate that bilinguals might find it easier to integrate the semantic information of an object with a category cue in its name into the category to which it belongs. Bilinguals appear to experience fewer violations of rules when categorizing atypical items with category cues in their names than atypical items without cues.

As was discussed previously for Liu et al.'s study (2010), two explanations can account for the current findings based on Lupyan's label-feedback hypothesis. The first explanation is that when Chinese-English bilinguals saw a target picture, the picture was presumed to quickly activate both its English and Chinese names. The activation of picture labels in the categorization task sends feedback to the conceptual level and temporarily warps the semantic space. More specifically, the category label and the category cue in an object's Chinese name would have activated the most diagnostic features of the category to a higher degree than the non-diagnostic features. For atypical exemplars of the category, there would be more overlap between the features activated from the category label and the object picture than when there was no category cue in the

Chinese name, thus facilitating categorization. Based on this explanation, the current findings provide supporting evidence for the language non-selective activation view in bilinguals (Dijkstra & Van Heuven, 2002), which claims that bilinguals activate information from both of their languages simultaneously even when they are using only one of their languages. Chinese-English bilinguals' categorization processes are constantly influenced by their two languages. Even when they are doing the categorization task in English, the information in objects' Chinese names can still influence their categorization processes.

The second explanation for the current findings is that bilingual participants' organization of category representations could be permanently changed under the long-term effects of everyday usage of objects' Chinese names. More specifically, objects that have a category cue in their Chinese names are more strongly associated with the most diagnostic features of the category through the feedback from everyday usage of Chinese labels, resulting in them being stored in the center of the category, even for an atypical exemplar of the category, making them easier to categorize. On the contrary, objects that do not have a category cue in their Chinese names are stored in the periphery of the category space, thus making them difficult to categorize. In Experiment 1, participants categorized pictured objects without the objects' labels being presented in the task. As aforementioned, various studies have suggested that pictures can be categorized faster than they are named (e.g., Irwin & Lupker, 1983; Strijkers et al., 2011). Therefore, in the current Experiment, it is possible that participants categorized a target picture before its label was highly activated, thus the second explanation could be a more likely option than the first one.

In summary, the ERP results were consistent with the behavioural results in Experiment 1. Together they indicated that verbal labels have an effect on object categorization. Having a category level cue in an object's name enhances categorization, especially for atypical items. The results also demonstrated that the category level cue embedded in an object's L1 name has an effect on bilinguals' categorization processes, even when they are doing the task in L2, and were put into an L2-speaking environment.

The current results reinforced and extended Liu et al.'s findings (2010) in several ways. First, in Liu et al.'s study, Chinese speakers showed a reduced typicality effect compared to English speakers when categorizing pictured objects that have a category cue in their Chinese names. Liu et al. argued that this difference between Chinese and English speakers should be attributed to the category information embedded in the objects' Chinese names: the category cue in an object's Chinese name facilitated categorization of the object in Chinese speakers, thus reducing the influence of typicality. English speakers showed no such effect because the category cues in the objects' Chinese names were not available to them. However, we cannot make such inferences confidently because the observed difference could be explained in other ways, like Chinese speakers are just not sensitive to typicality when categorizing pictured objects. In the current study, objects that do not have a category cue in their Chinese names were added. Results showed that the typicality effect was reduced in Chinese speakers when they were categorizing pictured objects with cues compared to objects without cues. On the other hand, English speakers showed a strong typicality effect for both objects with and without cues. These results further confirmed Liu et al.'s findings and provided compelling evidence that the reduced typicality effect observed in Chinese speakers was due to the category cue embedded in the objects' Chinese names. Second, the current results further extended Liu et al.'s findings to Chinese-English bilinguals, demonstrating that bilinguals can make use of the category information embedded in an object's Chinese name even when they are doing the categorization task in English. The experience of learning a second language did not eliminate the faciliatory effects from an object's L1 name on bilinguals' categorization process.

There are still some limitations in Experiment 1. First, some items were excluded from the original larger stimulus list because of low name agreement. It can be difficult to distinguish some items in pictorial forms, such as violin, viola, and cello. Because of the relatively small number of items (21) in Experiment 1, each stimulus was presented twice in the categorization task in order to get a clear ERP signal after averaging. The behavioural results showed that this repeated presentation of stimuli influenced participants' responses. Results were different for the first vs. second presentation. The faciliatory effects of a category cue embedded in objects' Chinese names only showed up in the first exposure data. However, in the ERP data analyses, data were collapsed across both the first and the second exposure, because the coding method I used for the ERP data would not allow me to separate data from the first exposure and the second exposure (the ERP data were coded just based on conditions). This might have had an influence on the ERP results, and could be the reason that in the analyses of English sessions, no significant triple interaction in the N300 component was observed. Therefore, in Experiment 2, word stimuli instead of pictures were used as targets. Because name agreement was not a problem, more items could be included, and there was no need to repeat them in the experimental task.

In addition, the filler pairs in Experiment 1 were created by re-pairing the critical category label-image pairs. This was done to prevent participants from developing a link between a certain image and a certain response type. For example, participants might link a picture of robin with a *yes* response in the first presentation, and then they would quickly make a *yes* response when they saw a robin picture for the second time without categorization. The re-pairing method used in Experiment 1 resulted in each target picture being presented four times in the categorization task, which could have influenced participants' responses on critical trials and weakened the results. In Experiment 2, because there was no need to repeat stimulus items, new items that were different from critical stimuli were used as fillers, so that each critical target was presented only once in the categorization task.

Another limitation in Experiment 1 is that although bilinguals did the English session in a pure English environment, half of the bilinguals did the Chinese session first. This could have given them some clues that bilingualism and Chinese were of interest in the study and possibly had some influence on their results in the English session. Therefore, in Experiment 2, bilingual participants were put into an English monolingual mode to the fullest possible extent. The use of word targets instead of pictures made it possible to make it clearer to participants that only their knowledge of English was required.

2.5 Experiment 2

Experiment 2 further examined whether having a category level cue in an object's verbal label results in it being categorized more easily, especially when the object is an atypical item of the category. The present experiment extended Experiment 1 by using English word stimuli instead of pictures as targets and only an English-speaking environment for bilingual participants. As aforementioned, using word targets in a categorization task could shed light on the question of whether our semantic space is temporarily or permanently affected by label feedback. If there were no temporary influences from the activation of verbal labels, similar results should be observed in Experiment 1 and Experiment 2, because both experiments would only reflect the long-term effects of verbal labels. On the contrary, if the activation of verbal labels at the time of categorization processing helps, stronger effects in Experiment 2 should be observed, because with the object labels presented in the categorization task, both short-term and long-term effects of verbal labels should be operating in the task. Furthermore, the use of word targets instead of pictures allowed more items to be included in the stimulus list, so there was no need to repeat them in the experimental task. New words that were different from critical target words were used to create filler trials with *no* response, so that each critical target word was presented only once to each participant. In addition, the use of word targets further reinforced the English nature of the experiment.

In Experiment 1, each bilingual participant was tested in both Chinese and English. Although bilingual participants did the English and Chinese sessions separately in a pure language environment, according to Grosjean (2001) this knowledge that they were taking part in a study of bilingualism could have influenced the level of activation of their two languages in the experiment. Grosjean (2001) proposed the bilingual language mode hypothesis. Language mode is defined as "the state of activation of the bilingual's languages and language processing mechanisms at a given point in time" (Grosjean, 2001, p. 3). According to the language mode hypothesis, a bilingual's language mode is a continuum ranging from a monolingual language mode, through an intermediate language mode, to a bilingual language mode, depending upon the activation levels of a bilingual's two languages. Grosjean suggested that a participant's language mode at the time of testing is a potential confound in the earlier studies on bilingualism. A number of factors may have moved the participants in those studies closer to an intermediate language mode on the language mode continuum than to a monolingual language mode, resulting in an overestimation of the extent to which both languages of a bilingual are typically active. For example, participants often knew that they were participating in an experiment on bilingualism, they were sometimes tested by bilingual experimenters fluent in both languages, and both languages were used in the same experimental session (e.g., in a bilingual Stroop task where words are presented in one language while colour naming is performed in another language), or both bilingual's two languages were tested in two experimental sessions with the same participant group (e.g., Marian & Spivey, 2003; Spivey & Marian, 1999). Several studies have provided evidence that nonselective language activation is constrained by nonlinguistic factors, such as external language context (Linck, Kroll, & Sunderman, 2009), task demands (Lemhöfer & Dijkstra, 2004), and cultural cues (Berkes et al., 2018; Zhang et al., 2013). In Experiment 1, when the bilingual participants were tested in English, the knowledge that Chinese was relevant to the study could have encouraged them to keep their Chinese active (but less active than English) and mad e it easier to observe the effects of a category level cue embedded in objects' Chinese names.

In Experiment 2, bilingual participants were put into an English monolingual mode to the fullest extent possible. Participants were tested only in English; no other languages were involved in the experiment. Participants were greeted in English, and all conversation and consent forms were in English. In addition, bilingual participants were recruited via a filter system in the research participation pool at the University of Western Ontario, and advertisements posted on social media groups for Chinese students. Therefore, the study was directed only to native Chinese speakers without the requirements of bilingualism being listed in study information. There was no clue showing that bilingualism and Chinese were involved in the experiment.

In summary, the same experimental paradigm was used as in Experiment 1, but English word labels of target items were used instead of images and bilinguals completed the task only in English. The typicality effect in Chinese-English bilinguals was expected to be smaller for English words with category cue in their Chinese name than for items without this cue, both in the response time data and in the N400 ERP component, whereas English monolinguals should show no such effect because the category information in objects' Chinese names is not available to them. Previous studies investigating the typicality effect with ERPs have found that typicality effects in linguistic stimuli are marked by the negative N400 component, such that atypical items of a category elicit a larger N400 than typical items (Kutas & Federmeier, 2000; Kutas & Hillyard, 1980). The N300 component was not of interest in the present study because it is specifically elicited for pictorial stimuli based on previous studies (Hauk et al., 2007; Kiefer, 2001).

2.5.1 Method

2.5.1.1 Participants

Thirty-nine Chinese-English bilinguals (mean age 22, range 18-46, 23 female) and 29 English monolinguals (mean age 18, range 18-21, 10 female) were recruited via the research participation pool at the University of Western Ontario and advertisements on WeChat groups. Participants received course credit or money for their participation. None of the participants had participated in Experiment 1. Data from eleven bilinguals (ten of them had low accuracy on the categorization task (< 63%), one had poor ERP recording) and one English monolingual (poor ERP recording) were excluded from the analyses, leaving 28 Chinese-English bilinguals and 28 English monolinguals in the final sample. The first language of all bilinguals in the final sample was Mandarin. All bilinguals were born in China (including Taiwan), had lived in China for a mean duration of 15.75 years (range 2-25), and had lived in Canada for a mean duration of 7.39 years (range 2-21). The bilinguals rated their English language skills on a scale of 1 (none) to 10 (native-like fluency); the means were 8.96 for spoken comprehension, 8.03 for reading, 8.22 for speaking, and 7.35 for writing. The bilinguals also self-reported the percentage of time that they currently exposed to each of their language in their daily activities. The bilinguals were exposed to English for a mean of 52% of the time, and they were exposed to Mandarin Chinese for a mean of 41% of the time.

2.5.1.2 Materials

Critical stimuli for this Experiment were the original stimulus set normed in Pilot Study 1, which consists of 13 categories and 108 items (in contrast to the subset of 11 categories and 84 items used in Experiment 1). Half of the objects were typical, half of them were atypical (See Table 1 for mean typicality ratings). Half of the objects had a category label in their Chinese names, half of them did not. All of the critical stimuli were *yes* decisions (see Appendix B for the list of critical stimuli). Another 108 category label-object name pairs were created as filler stimuli to include *no* decisions. The same set of category labels were used in filler pairs as in critical pairs. The breakdown of the target words used in filler pairs was as follows: 56 items from the 13 categories, and 52 items from other categories (this was done because not enough filler stimuli could be found within the 13 categories). Half of the filler items were typical, half of them were atypical. Half of filler items had a category label in their Chinese names, half of them did not.

2.5.1.3 Procedure

A category label-object name matching task was used (Figure 2.6). Participants first saw a 500 ms fixation cross, followed by a category label (e.g., *BIRD*) for 500 ms, then followed by a word (e.g., *robin*). Participants were instructed to judge whether or not the concept represented by the second word is an example of the category represented by the first word. All category label-word pairs were presented only once to each participant in a random order. A total of 216 trials were presented, including 108 critical trials that required a *yes* response (27 trials per condition), 108 filler trials that required a *no* response, and 12 practice trials. The study was conducted in one session. Both English monolinguals and Chinese-English bilinguals were tested only in English. All conversation and experimental materials (instructions, letter of information, consent forms, and debriefing) were in English. At the end of the experiment, participants were asked to fill in a questionnaire about their language background and, then, debriefed.

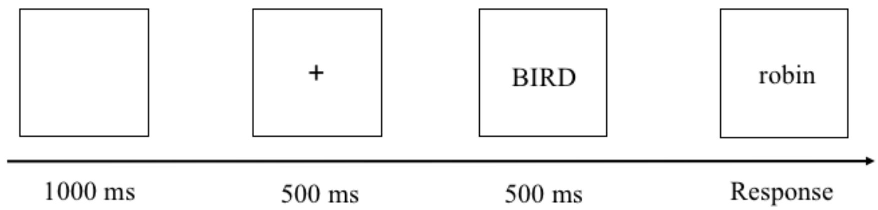

Figure 2.6. Experimental procedure in Experiment 2.

2.5.1.4 EEG recording and preprocessing

Recording, digitization of the EEG activity, and off-line analysis were done as in Experiment 1. The epochs of interest for target words were established to be from -200 to 1000 ms post-stimulus onset. Trials contaminated with activity greater than ±75 microvolts (μΩ) were excluded from the analysis (10.51 % of the trials were excluded for Chinese-English bilinguals; 9.82% of the trials were excluded for English monolinguals).

2.5.2 Results

2.5.2.1 Behavioural analyses

Incorrect responses (20.99% for bilinguals, 9.16% for English monolinguals), as well as response times that were shorter than 200 ms or longer than 2500 ms for bilinguals (3.76%) and response times that were shorter than 200 ms or longer than 1500 ms for English monolinguals (1.85%) were excluded from the analyses of the latency data. The mean response latencies and error rates are presented in Table 2.17. Bilingual participants had a much higher error rates (21%) compared to English monolinguals (9%). This could be due to the fact that there were some targets with very low word frequency (e.g., tuxedo, quartz). Bilinguals' incorrect responses likely reflect their lack of knowledge of these words, so the error rate data in Experiment 2 might not reflect the categorization processes accurately. Therefore, only response time data were analyzed in the behavioural analyses.

Table 2.17.

Mean Response Times (in ms) and Percentage Error Rates (between brackets) in Experiment 2.

	Cue			NoCue		
	Typical	Atypical	Typicality effect	Typical	Atypical	Typicality effect
Bilingual	932 (11.37)	1025 (31.47)	93 (20.1)	915 (14.28)	1062 (26.58)	147 (12.30)
English monolingual	595 (4.10)	668 (13.49)	73 (9.39)	596 (5.68)	663 (13.35)	67 (7.67)

RTs from bilinguals and English monolinguals were analyzed with LME models. RTs were fitted in Model 11 with Typicality (Typical vs. Atypical, sum coded), Word Type (Cue vs. NoCue, sum coded), Language Group (Bilingual vs. English Monolingual, sum coded), and Word Frequency (CELEX_W, without interactions with other fixed factors) as fixed effects, participants and items as random intercepts, and by-participant random slopes for the effects of Typicality and Word Type (without interaction). Word Frequency was included as a covariate that could influence RTs of the target words. Results of the tests evaluating the fixed effects included in the model are presented in Table 2.18.

Table 2.18.

Analysis of Variance Table for Model 11 (RTs).

	χ^2	*df*	*p*
Typicality	24.89	1	< .001 ***
Word Type	0.02	1	*ns*
Language Group	48.80	1	< .001 ***
Word Frequency	10.25		.001 **
Typicality x Word Type	1.30	1	*ns*
Typicality x Language Group	5.96	1	.01 *
Word Type x Language Group	0.14	1	*ns*
Typicality x Word Type x Language Group	4.16	1	.04 *

There was a significant main effect of Typicality ($p < .001$), a significant main effect of Language Group ($p < .001$), and a significant main effect of Word Frequency ($p = .001$). Typical items were responded to 83 ms faster than atypical items. English monolinguals responded 349 ms faster than bilinguals. There was a significant interaction between Typicality and Language Group ($p = .01$). The typicality effect was 50 ms smaller for English monolinguals than for bilinguals. Most importantly, there was a significant three-way interaction between Typicality, Word Type, and Language Group ($p = .04$). The typicality effects were smaller for items with cues (93 ms) than items without cues (147 ms) in bilinguals but were similar for items with cues (73 ms) and items without cues (67 ms) in English monolinguals. Separate analyses for each language group revealed that bilinguals showed a weak trend towards a Typicality x Word Type interaction, $\chi^2(1) = 1.99$, $p = .15$, but the interaction was absent for English monolinguals, $\chi^2(1) = 0.004$. Likelihood ratio tests were conducted to measure the effect size of the three-way interaction. AIC of the full model with the triple interaction and the reduced model without the interaction was compared. A relative likelihood of 2.97 was found, indicating that the full model was 2.97 times more likely than the reduced model to minimize information loss.

2.5.2.2 ERP analyses

The data from the same set of electrodes as in Experiment 1 were included in analyses (see Figure 2.2). The negative going N400 component peaked at around 400 ms and was measured in the 375-500 ms time window. Figures 2.7 and 2.8 show the grand average waveforms in microvolts (μV) evoked in response to the four conditions and voltage maps showing the typicality effect on N400 components for Chinese-English bilinguals and English monolinguals respectively.

N400 (375-500 ms)

Mean amplitudes in the 375 ms to 500 ms time window were analyzed with LME models. Model 12 was fitted with Typicality (Typical vs. Atypical, sum coded), Word Type (Cue vs. NoCue, sum coded), and Language Group (Bilingual vs. English Monolingual, sum coded) as fixed effects, participants as random intercept, and by-participant random slopes for the effects of Typicality and Word Type (without interaction). Results of the tests evaluating the fixed effects included in the model are presented in Table 2.19.

Table 2.19.

Analysis of Variance Table for Model 12 (N400 mean amplitudes).

	χ^2	*df*	*p*
Typicality	11.37	1	< .001 ***
Word Type	3.72	1	.05
Language Group	1.68	1	*ns*
Typicality x Word Type	2.69	1	.10
Typicality x Language Group	1.95	1	*ns*
Word Type x Language Group	0.27	1	*ns*
Typicality x Word Type x Language Group	4.50	1	.03 *

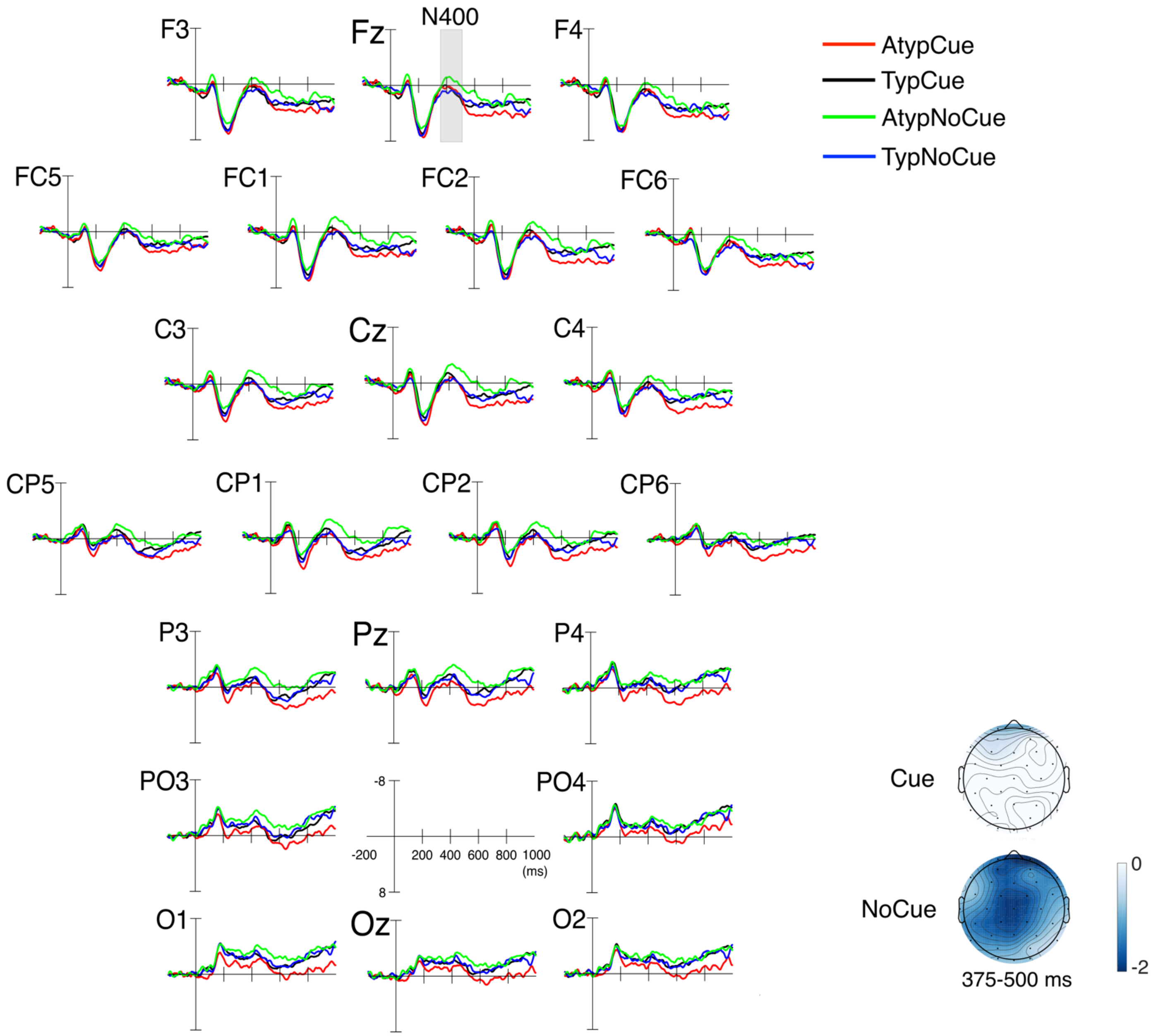

Figure 2.7. Grand average waveforms in microvolts (μV) and voltage maps of the typicality effect (Atypical - Typical) in the N400 component for Chinese-English bilinguals in Experiment 2.

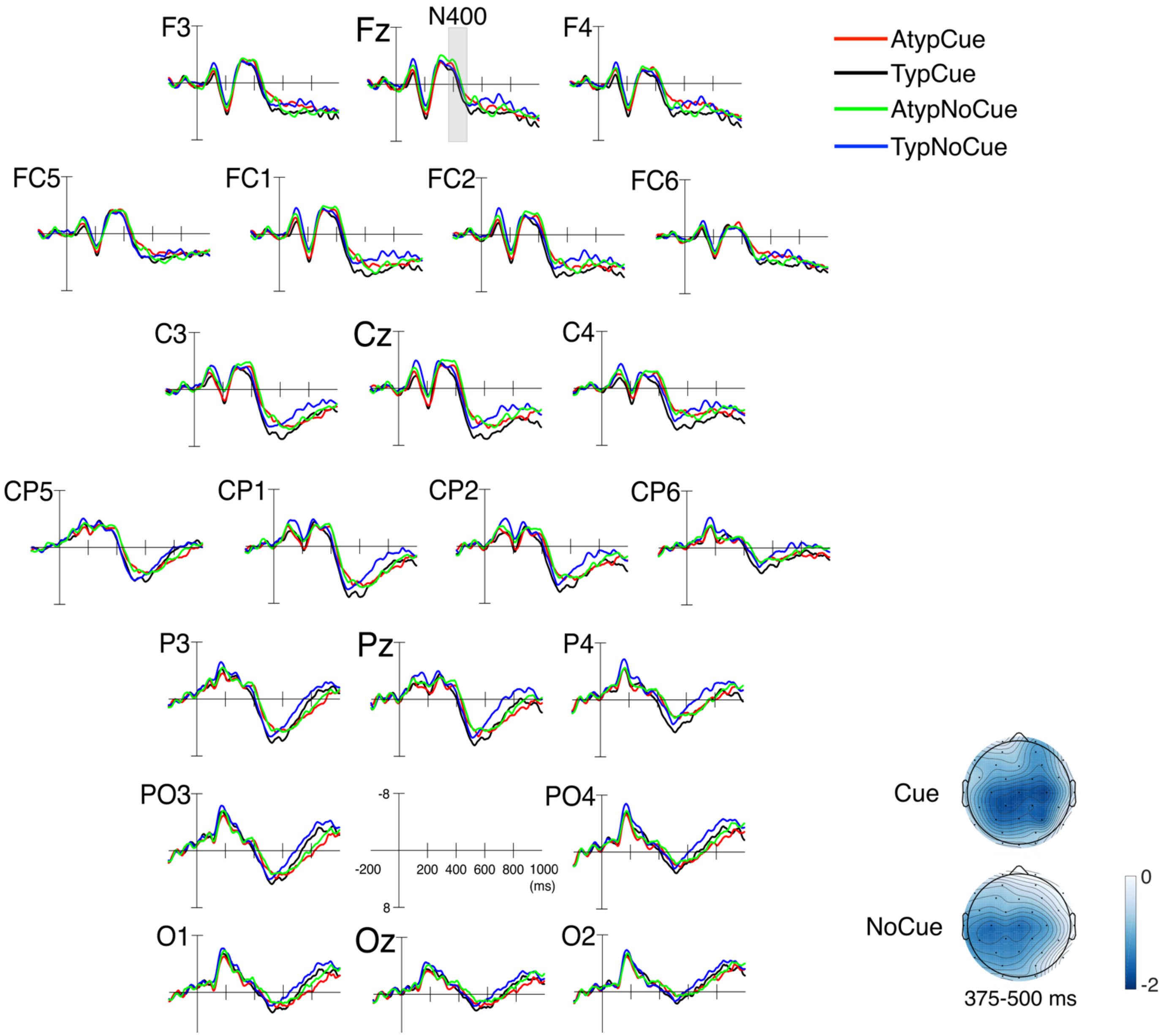

Figure 2.8. Grand average waveforms in microvolts (μV) and voltage maps of the typicality effect (Atypical - Typical) in the N400 component for English monolinguals in Experiment 2.

There was a significant main effect of Typicality ($p < .001$). Atypical items elicited a more negative N400 than typical items. Importantly, there was a significant three-way interaction between Word Type, Typicality, and Language Group ($p =.03$). Separate analyses on each language group revealed that the Typicality x Word Type interaction was significant for bilinguals, $\chi^2(1) = 7.30$, $p = .006$, but not for monolinguals, $\chi^2(1) = 0.12$. The typicality effects were smaller for items with cues than items without cues in bilinguals but were similar for items with cues and items without cues in English monolinguals. Likelihood ratio tests were conducted to measure the effect size of the three-way interaction. AIC of the full model with the triple interaction and the reduced model without the interaction was compared. A relative likelihood of 3.63 was found, indicating that the full model was 3.63 times more likely than the reduced model to minimize information loss.

To sum up the results, the behavioural and the ERP results were consistent in Experiment 2. A significant three-way interaction between Word Type, Typicality, and Language Group was found in both behavioural and ERP data. The typicality effects were similar for items with cues and items without cues in their Chinese name in English monolinguals, but were smaller for items with cues than items without cues in bilinguals. This finding for monolinguals indicates that the words in the cue and no cue conditions were well matched for the size of the typicality effect within English. Therefore, the finding that Chinese-English bilinguals categorized English words with category cues in their Chinese names more easily than English words without cues in their Chinese names provides evidence that their knowledge of Chinese influenced the ease with which they categorized English words. That is, the category level cue embedded in an object's L1 name has an effect on bilinguals' categorization processes, even when they are doing the task in L2 and are put in a pure L2-speaking environment.

2.5.3 Discussion

In Experiment 2, I examined the effects of Chinese word structure on bilinguals' categorization processes with English word stimuli. More items were included as compared to Experiment 1, so there was no need to repeat stimuli in the experimental task. Using word stimuli further reinforced the English nature of the experiment. Furthermore, by using word targets in Experiment 2 and comparing the current results with the results observed in Experiment 1, we can better understand the nature of the label feedback effects, that is, whether they affect our semantic space temporarily or permanently. Response times and brain responses were measured as Chinese-English bilinguals and English monolinguals categorized English word labels of typical and atypical objects. The typicality effect was reflected in response times and in the N400 ERP component. Comparisons of bilinguals and English monolinguals in the RT and N400 data showed that the typicality effects were smaller for items with cues than items without cues in bilinguals, while English monolinguals showed no such difference. The N400 component has been broadly used as an index of the semantic congruency of a word to the whole context (see Kutas & Federmeier, 2011, for a review). A more negative N400 is thought to be associated with more semantic violation. In categorization processes, categorizing an atypical item produces more sense of semantic violation than categorizing a typical item, because atypical items usually contain more semantic features that are not commonly seen in the category members. Thus, the N400 component has also been used as an ERP marker for the typicality effects in linguistic stimuli (Kutas & Federmeier, 2000; Kutas & Hillyard, 1980). Therefore, findings in Experiment 2 further suggested that bilinguals might experience less semantic violation in categorizing English words referring to atypical items when those words have category cues in their Chinese names than when they do not. The category information imbedded in objects' Chinese names facilitated bilinguals' categorization of English words and reduced the influence of typicality. In addition, these findings further supported the non-selective activation view in bilinguals, because all the experimental stimuli were presented in English, and there was no indication that Chinese was relevant in the experiment.

When compared to Experiment 1, stronger faciliatory effects of category cue in objects' Chinese names were observed in Experiment 2, especially in the ERP data. As mentioned before, one possible reason for this could be that the repeated presentation of stimuli in Experiment 1 attenuated the observed effects, especially in the ERP data where the data could only be analyzed over both presentations of the pictures. The other possible reason could be that in Experiment 2, bilingual participants' categorization processes were facilitated by both the short-term and long-term effects of object labels. In Experiment 2, a categorization task with word targets were used. Participants first saw a category label then followed by an object word. They made judgements as to whether the target word was an exemplar of the category. Participants' ongoing categorization processes could be influenced by the feedback from the activation of the target object label in the task. In the categorization task, the category label would have activated a range of typical features of the category. Then the target word and its Chinese translation would have then activated a range of features of the object. The category cue embedded in an object's Chinese name would have facilitated the activation of the most diagnostic features of the category, even when the object is an atypical exemplar of the category. Therefore, the perceptual features that were activated from a category label would have more overlap with the features activated from the feedback from a label with category cue than a label without cue, thus producing a faster response and less negative N400. In addition to the temporary faciliatory effects from the activation of object labels in the task, participants' categorization processes could also be affected by the long-term influences from their daily usage of the objects' Chinese labels. As aforementioned, through the feedback from daily usage of Chinese labels, category members that have a category cue in their Chinese names become more strongly associated with the most diagnostic features of the category, causing them to be stored closer together in the center of the category space, while members that do not have a category cue are stored in the periphery of the category space. The consequence is that objects with category cues were categorized more easily than objects without cues, especially for atypical exemplars of a category. Therefore, under the influences from both short-term and long-term effects of verbal labels, bilinguals showed stronger faciliatory effects of category cue on their categorization processes in Experiment 2 than in Experiment 1. This result was obtained despite the greater efforts made in Experiment 2 to ensure that bilinguals were in a monolingual mode during the experiment which could have reduced the impact of Chinese on English compared to Experiment 1.

Participants did two categorization tasks in Experiment 1 and 2, which I assumed involved extensive semantic processing. While it is highly possible that participants made decisions based on the semantic congruency between the category labels and the target objects, it could be argued that participants did the categorization task based only on phonological or lexical overlap between the category labels and the objects' Chinese names. For example, in Experiment 1, when bilingual participants saw the picture of an ostrich, the Chinese name *鸵鸟* was activated, which had the category label *鸟* embedded in it. Bilingual participants could have made the decision that an ostrich is a bird solely based on the overlap of the character *鸟* in the category label and the object's name. Similarly, in Experiment 2, bilinguals could have automatically translated the category labels and the object words into Chinese, then performed the categorization task based on phonological or lexical overlap between the category's and the object's Chinese labels. One could also argue that the faciliatory effects observed in Experiment 1 and Experiment 2 were lexical because the category label could have activated items with the label in their names, thus causing them to be responded to faster than items without the label in their names. For example, in Experiment 1, when bilinguals were tested in Chinese, the category label *鸟 (bird)* could have activated items with *鸟* in their Chinese names, causing them to be responded to faster than objects without *鸟* in their names. Although this argument is less likely when bilinguals were tested in English, especially in Experiment 2 where both category labels and targets were presented in English, bilingual participants could have automatically translated the category labels into Chinese, thus activating items with the category label in their names. If indeed this is the case that the faciliatory effects observed in Experiment 1 and Experiment 2 were only lexical, the current findings would still be interesting in that they provide evidence for the language non-selective activation view that claims that bilinguals activate the language not in use when doing a categorization task in another language.

However, I believe that the current findings reflect extensive semantic and categorization processing. Various studies with EPR have suggested that lexical information typically becomes available around 200 ms after stimulus onset in picture naming (Costa et al., 2009; Indefrey & Levelt, 2004; Strijkers et al., 2010) and shortly after 200 ms in word recognition tasks (Grainger & Holcomb, 2009; Hauk, Davis, Ford, Pulvermüller, & Marslen-Wilson, 2006). Phonological processing is believed to happen even earlier than, or along with, lexical processing, at around 200 ms (Grainger &

Holcomb, 2009; Grainger, Kiyonaga, & Holcomb, 2006; Hauk et al., 2006; Jouravlev, Lupker, & Jared, 2014). Other studies have also found that automatic translation from L2 to L1 in bilinguals took place at a late, post-lexical processing stage (around 400 ms), after word meaning retrieval (Thierry & Wu, 2007). In the current study, the faciliatory effects from an object's Chinese name were observed in several late ERP components (e.g., ELC: between 400 to 500 ms, and N400: between 375 to 500 ms), but not any early ERP components, except in Experiment 1, bilinguals appear to show some faciliatory effects of a category cue in the N200 component between 180-250 ms when they were tested in Chinese, but this effect in the N200 was absent when they were tested in English and in English monolinguals. The late ERP components observed in the current study (N400 and ELC) were believed to be related to semantic congruency and typicality effects in categorization in a number of previous studies (Kutas & Federmeier, 2011; Sitnikova et al., 2008, 2003). Therefore, it is unlikely that the effects observed in the current study are only due to the overlap at the phonological or lexical level.

2.6 Summary

The goal of the current study was to examine the effects of word structure on bilinguals' categorization processes, and to test the label-feedback hypothesis. Empirical evidence for the label-feedback hypothesis has demonstrated that verbal labels have an important role in category formation and categorization processes (e.g., Edmiston & Lupyan, 2015; Lupyan & Casasanto, 2015; Lupyan & Thompson-Schill, 2012). For example, in Liu et al.'s study (2010), which was a major source of inspiration for the current study, researchers investigated the effects of Chinese word structure on categorization processes. Native speakers of Chinese and English judged the category membership of pictures of typical and atypical exemplars that have a category cue embedded in their Chinese names. Results showed that the typicality effect was absent in Chinese speakers while English speakers showed a strong typicality effect. The results suggested that the category cue embedded in objects' Chinese names facilitated the categorization process in Chinese speakers and reduced the influence of typicality. Liu et al.'s study provided supporting evidence that word structure could influence our categorization processes, although the authors did not include a critical comparison group of objects without category cues in their Chinese names. However, only Chinese and English monolingual groups were tested in their study. The question of how word structure affects object categorization in bilinguals was not addressed. Therefore, in the current study, I further explored the effects of Chinese word structure on Chinese-English bilinguals' categorization processes with ERPs and tested the label-feedback hypothesis. More specifically, since bilinguals know two different languages and activate representations in both languages, the current study also investigated the question of whether the characteristics of a label could have an impact on bilinguals' categorization even when the language was not being used. Results from Experiment 1 and Experiment 2 revealed that category information in an object's Chinese name facilitated categorization of the object in Chinese-English bilinguals, even when they were tested in a pure English-speaking environment where no clue showed that Chinese was involved.

Two main findings were observed. First, category information in an object's L1 name facilitates categorization of the object in bilinguals, especially for atypical exemplars of the category. Second, the facilitation from objects' L1 names exists even when bilinguals are put in an L2-speaking environment where no clue shows that L1 is involved. These findings provide supporting evidence for the label-feedback hypothesis which states that labels can facilitate categorization by selectively activating the most diagnostic features of the category. In the current study, the activation of the category information embedded in an object's L1 name sends feedback to the conceptual level, resulting in the diagnostic features of the category being activated to a higher degree, thus facilitating categorization of the object. Alternatively, the feedback from daily usage of object labels could have changed the category representations in which category members that have a category cue in their names are represented in the center of the category space, while members do not have a cue are represented in the periphery of the category space, thus making objects with cues easier to categorize. The current results suggested that both processes were likely happening; bilinguals' L1 has an influence on their categorization process when only L2 is used.

In the current study, two categorization tasks were used: one with picture targets and one with word targets. Both categorization tasks required participants to make explicit decisions about the relationship between the category labels and the targets. Results showed that the structure of a verbal label has an influence on categorization process. However, from the current results we do not know whether or not the influence of word structure can penetrate non-verbal processes. In addition, although I believe that the findings in Experiment 1 and Experiment 2 are unlikely due only to the phonological or lexical overlap between the category labels and the objects' Chinese names, it is worthwhile to further test this argument in an early ERP time window in which lexical access is believed not yet to have happened. Therefore, in Chapter 3, I further examined the influences of word structure on object perception with a visual oddball detection task where no verbal processing was involved.

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3 The effects of word structure on object perception

Linguistic labels have been shown to have an important role in object perception. Sharing a verbal label for two objects could result in them being perceived more similarly than two objects do not share a name (e.g., Boutonnet, Dering, Viñas-Guasch, & Thierry, 2013; Jouravlev, Taikh, & Jared, 2018; Thierry, Athanasopoulos, Wiggett, Dering, & Kuipers, 2009). In addition, research from the bilingual literature has suggested that learning a new language that does not make a lexical distinction between two objects that use different labels in the first language could make bilinguals less sensitive to the distinctions between the objects than a monolingual of that language (Athanasopoulos, 2009; Athanasopoulos, Dering, Wiggett, Kuipers, & Thierry, 2010). For example, Athanasopoulos et al. (2010) investigated the effects of verbal labels on bilinguals' colour perception, and specifically whether the effects of a bilinguals' L1 were attenuated by extensive exposure to an L2 environment. Greek-English bilinguals did a visual oddball detection task where shades of dark and light blue were used as standards and deviants (Greek uses *ghalazio* and *ble* for light and dark blue respectively, but English uses the term *blue* for both). Results showed that bilinguals who had lived in an English country for a relatively long time (M = 3.5 years) became less sensitive to the dark blue and light blue distinction as compared to short-stay bilinguals. Nonetheless, most of the existing research on the interaction between labels and perception has focused on the effects of sharing a label for two objects compared to using two labels for the two objects, in both monolingual and bilingual literature. Few of them have considered whether the characteristics of the verbal label itself could have an influence on object perception.

One study done by Maier, Glage, Hohlfeld, and Abdel Rahman (2014) investigated the influence of semantic content associated with verbal labels on object perception. They proposed that the semantic information associated with verbal labels could augment the contribution of diagnostic perceptual features resulting from the activation of verbal labels. Participants were asked to learn unfamiliar objects which were associated with either bare labels lacking explicit semantic content or labels that were accompanied by enriched semantic information about the specific meaning of the label. Participants then completed an oddball detection task two to three days after learning. Results showed that newly acquired verbal labels modulated object perception in the early ERP component (100-150 ms after stimulus onset); objects that shared the same verbal label were perceived more similarly than objects having different labels. However, this effect was not influenced by enriched semantic information associated with the labels. Maier and colleagues concluded that the activation of bare labels alone was sufficient to produce an effect on categorical perception. Although Maier and colleagues did not find any enhanced influence of semantic content associated with verbal labels on object perception, other characteristics of labels, like the different structures of verbal labels, could potentially affect object perception. As was revealed in Chapter 2, the construction of verbal labels has an influence on the categorization process. Having a category level cue in an object's verbal label made it easier to categorize, especially when the object is an atypical exemplar of the category. According to the label-feedback hypothesis, this effect of category level information embedded in verbal labels should penetrate perceptual processes, and thus enhance categorical perception.

3.1 Rationale for the Present Study

The present study examined whether sharing a category level cue in objects' verbal labels enhances perceived similarity. Following previous studies examining questions of language-perception interaction, a visual oddball paradigm was used. Unlike previous studies that used objects that share a verbal label (e.g., Athanasopoulos et al., 2010; Boutonnet et al., 2013), objects with different verbal label structures were used. The present study investigated the perception of typical and atypical exemplars of a category that share a category level cue in their Chinese names (e.g., *robin, ostrich*) and the perception of typical and atypical exemplars of the category that do not share a category level cue in their Chinese names (e.g., *pigeon, penguin*) in bilinguals who have lived in Canada for a relatively long time, bilinguals who have lived in Canada for a short period of time, and English monolinguals. In addition, the present study also investigated whether immersion in an L2-speaking environment makes bilinguals less sensitive to the distinctions between two objects that have different names in bilingual's L1 but share a common verbal label in L2.

As mentioned in the general introduction, in a visual oddball detection task, participants identify infrequent visual target stimuli within a continuous flow of rapidly presented stimuli. The critical stimuli in this design are nontarget stimuli. Within the critical stimuli, a standard stimulus is presented with a high local probability (e.g., 80%), and a deviant stimulus is presented with a low local probability (e.g., 15%). The presentation of a deviant stimulus in a sequence of standards would evoke a visual mismatch negativity (vMMN) in an early time window (usually peaking at around 150 to 250 ms). The vMMN effect (deviants eliciting a more negative vMMN than standards) has been broadly used as an index of perceived difference/similarity between objects, and it was believed that specific lexical information is unlikely to be available in this early time window (Strijkers, Holcomb, & Costa, 2011; Thierry, 2016).

There are two possible explanations about how verbal labels could affect perceptual processes in a visual oddball detection task based on the label-feedback hypothesis. In the oddball detection task, participants passively view a series of pictures, and made responses only to the targets, while of interest are their brain responses to the "distractor" pictures. First, based on the label-feedback hypothesis, participants' ongoing perceptual processes could be influenced by the feedback from the on-line activation of the object label when they are doing the task. More specifically, in an oddball detection task, a sequence of the standard stimulus would activate the label for that stimulus, and the label would then activate a range of perceptual features of the object. Then when a deviant stimulus is presented, the picture would activate a range of perceptual features of the deviant object. If the standard has a category cue in its Chinese name, then the most diagnostic features of the category would be activated to a higher degree than the non-diagnostic features through the feedback from the category cue embedded in the labels. As a result, the relevant features activated from the feedback from the label for the standard would highly overlap with the features activated for the deviant, thus producing a reduced vMMN effect.

The alternative explanation is that the organization of our conceptual representations would have been changed through everyday usage of verbal labels. According to the label-feedback hypothesis, labels can selectively activate features that are typical or diagnostic of the category. Having a category cue in an object's name would result in features that are diagnostic of the category being activated each time the object is encountered. Through everyday usage of labels, objects that have a category cue in their names become more strongly associated with the most diagnostic features of the category and are pulled closer together in the center of the category, even if it is an atypical exemplar of the category. As a result, objects that share a category cue are perceived more similarly in an oddball detection task because they are represented closer together in the semantic space, thus producing a reduced vMMN effect.

Based on the label-feedback hypothesis, it was predicted that typical and atypical exemplars sharing a category level cue in their Chinese names would be perceived as more similar by Chinese speakers than exemplars that do not share a category cue. Consequently, the vMMN effect should be smaller for typical and atypical exemplars sharing a category level cue in their Chinese names than exemplars that do not share a cue. It was also predicted that long-stay Chinese-English bilinguals would perceive typical and atypical exemplars sharing a category level cue in their Chinese names as less similar than short-stay bilinguals. As bilinguals live longer in an L2-speaking country, their object perception becomes less influenced by a linguistic cue that exists only in the object's Chinese names.

3.2 Method

3.2.1 Participants

Thirty-one short-stay Chinese-English bilinguals (mean age 19, range 18-28, 22 female), 32 long-stay Chinese-English bilinguals (mean age 20, range 17-50, 22 female) and 28 native English speakers without any knowledge of Chinese (mean age 18, range 17-20, 15 female) were recruited via the research participation pool at the University of

Western Ontario. Participants received course credit for their participation. None of the participants had participated in Study 1. Data from three short-stay bilinguals (poor ERP recording), and four long-stay bilinguals (two of them did not complete the experiment, two had poor ERP recording) were excluded from analyses, leaving 28 short-stay bilinguals, 28 long-stay bilinguals, and 28 native English speakers in the final sample. The first language of all bilinguals in the final sample was Mandarin. All bilinguals were born in China (including Taiwan). Short-stay bilinguals had lived in China for a mean duration of 18.74 years (range 16-28), and had lived in Canada for a mean duration of 0.6 year (range 0-1.5). Long-stay bilinguals had lived in China for a mean duration of 14.57 years (range 1-20), and had lived in Canada for a mean duration of 4.14 years (range 2-9). All bilinguals rated their English language skills on a scale of 1 (none) to 10 (native-like fluency). For short-stay bilinguals, the means were 7.14 for spoken comprehension, 7.10 for reading, 6.17 for speaking, and 6.32 for writing. For long-stay bilinguals, the means were 7.67 for spoken comprehension, 7.32 for reading, 7.17 for speaking, and 6.53 for writing. The bilinguals also self-reported the percentage of time that they currently exposed to each of their language in their daily activities. The short-stay bilinguals were exposed to English for a mean of 36% of the time, and they were exposed to Mandarin Chinese for a mean of 63% of the time. The long-stay bilinguals were exposed to English for a mean of 41% of the time, and they were exposed to Mandarin Chinese for a mean of 55% of the time.

3.2.2 Materials

The stimuli for this study were images of a robin, an ostrich, a pigeon, a penguin, and a squirrel. The robin, ostrich, pigeon, and penguin images were critical stimuli; the image of a squirrel was the target to which participants responded. Robin and ostrich share the category cue *bird* in their Chinese names while pigeon and penguin do not. Robin and pigeon were typical items; ostrich and penguin were atypical items. The stimuli were selected based on the typicality rating data in Pilot Study 1 (robin: M =90.4; ostrich: M = 64.5; pigeon: M = 93.5; penguin: M = 54.26) and name agreement data in Pilot Study 2 (robin: 63%; ostrich: 85%; pigeon: 64%; penguin: 96%). (Note: some participants named robin (24%) and pigeon (29%) as *bird*, which resulted in the relatively low name agreement data for them.)

3.2.3 Procedure

Participants viewed 4 blocks of 400 images. Within each block, a standard stimulus was presented with a high probability (80% of trials) and a deviant stimulus was presented with a low probability (15% of trials). On 5% of trials, the image of the target object was presented. Each image was presented for 300 ms. Variable interstimulus intervals, ranging from 400 ms to 600 ms were used. Participants were instructed to view all images passively and to press a button whenever they detected an image of a squirrel that served as the target. The order of items in each block of trials was pseudorandomized in such a way that (a) two deviants or two targets did not appear next to each other and (b) there were at least three standards in a row before a deviant was presented. To control for perceptual differences between the stimuli and ensure that comparisons reflect deviancy and not inherent perceptual differences between the standards and deviants, each of the four pictures served as both standards and deviants. In Block 1, robins were used as standards and ostriches as deviants. In Block 2, ostriches were used as standards and robins as deviants. In Block 3, pigeons were used as standards and penguins as deviants. In Block 4, penguins were used as standards and pigeons were used as deviants (see Figure 3.1). The order of blocks was counterbalanced across participants. At the end of the experiment, participants were asked to fill in a questionnaire about their language background and, then, debriefed.

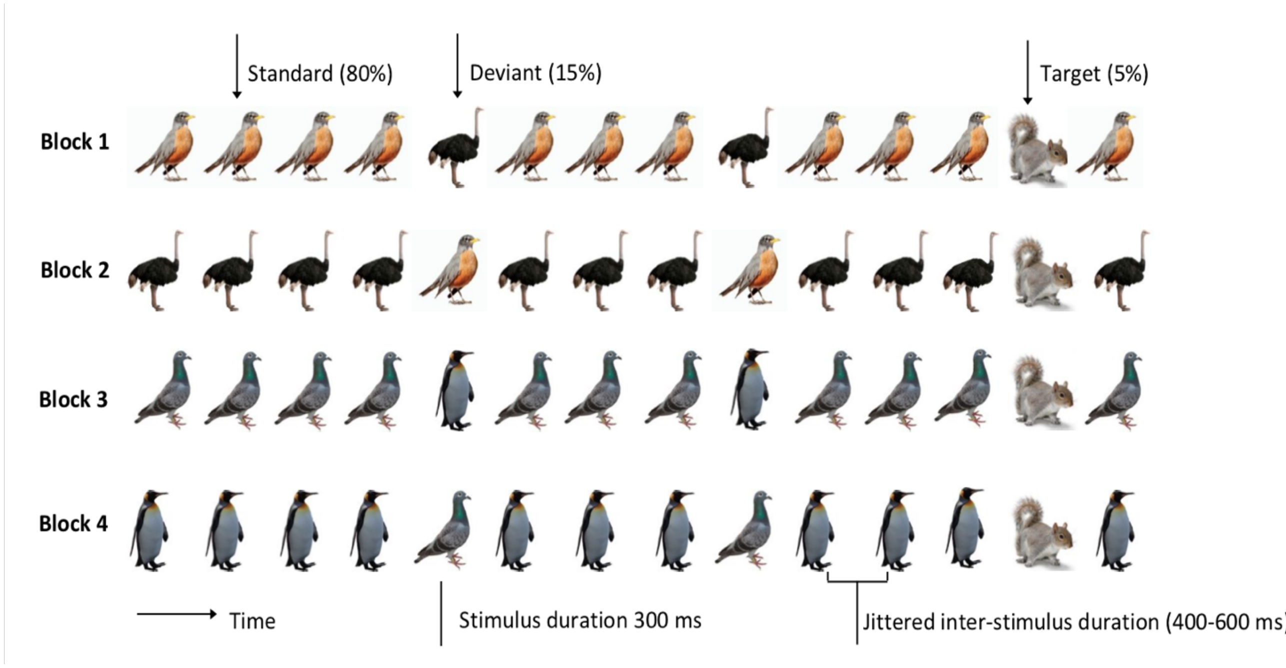

Figure 3.1. Experimental procedure in Study 2.

3.2.4 EEG recording and preprocessing

Recording, digitization of the EEG activity, and off-line analysis were done as in Experiment 1 and 2. The epochs of interest for standard and deviant images were established to be from -100 to 600 ms post-stimulus onset. Trials contaminated with activity greater than ±75 microvolts (μΩ) were excluded from the analysis (2.64 % of the trials were excluded for short-stay bilinguals, 5.24% for long-stay bilinguals, 4.65% for English speakers).

3.3 Results

Based on previous studies measuring vMMN (e.g., Boutonnet et al., 2013; Jouravlev et al., 2018), the data from 5 electrodes in the parieto-occipital region (PO3, PO4, O1, Oz, and O2) were included in the analyses (see Figure 3.2). For each participant, the data from the 5 electrodes were averaged. The component of most interest was the N1, or so-called vMMN. The negative going N1 component peaked at around 160 ms and was measured in the 140-180 ms time window. To ensure that ERPs reflect only the deviancy effect rather than specific perceptual characteristics of stimuli, ERPs elicited by robin and ostrich were averaged when they were presented as standards and, further, when they were presented as deviants. Thus, there was one standard and one deviant ERP response to *robin/ostrich* stimuli. Similarly, ERPs elicited by *pigeon* and *penguin* on standard and deviant trials were averaged, leaving one standard and one deviant response to *pigeon/penguin* stimuli. Figure 3.3 shows the grand average waveforms in microvolts (µV) to standards and deviants elicited by the *robin/ostrich* pair and *pigeon/penguin* pair and voltage maps for the vMMN effect for short-stay bilinguals, long-stay bilinguals, and English monolingual. To further test for any potential perceptual differences in the pair *robin/ostrich* vs. *pigeon/penguin*, the mean amplitudes of the P1 evoked just by standard stimuli in each of the four experimental blocks were analyzed. The positive going P1 component peaked at around 120 ms and was measured in the 100-140 ms time window.

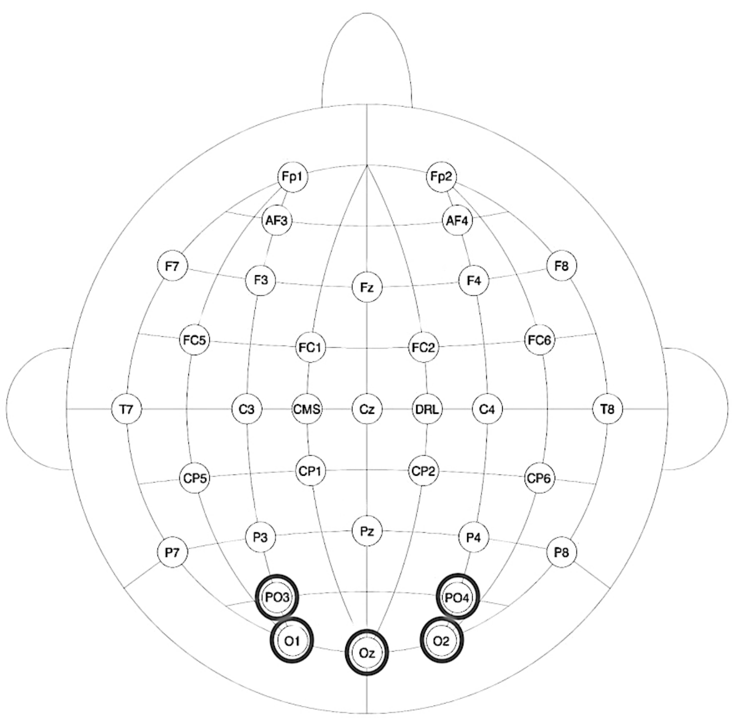

Figure 3.2. Electrode montage for Study 2. Circles indicate electrodes included in the analysis.

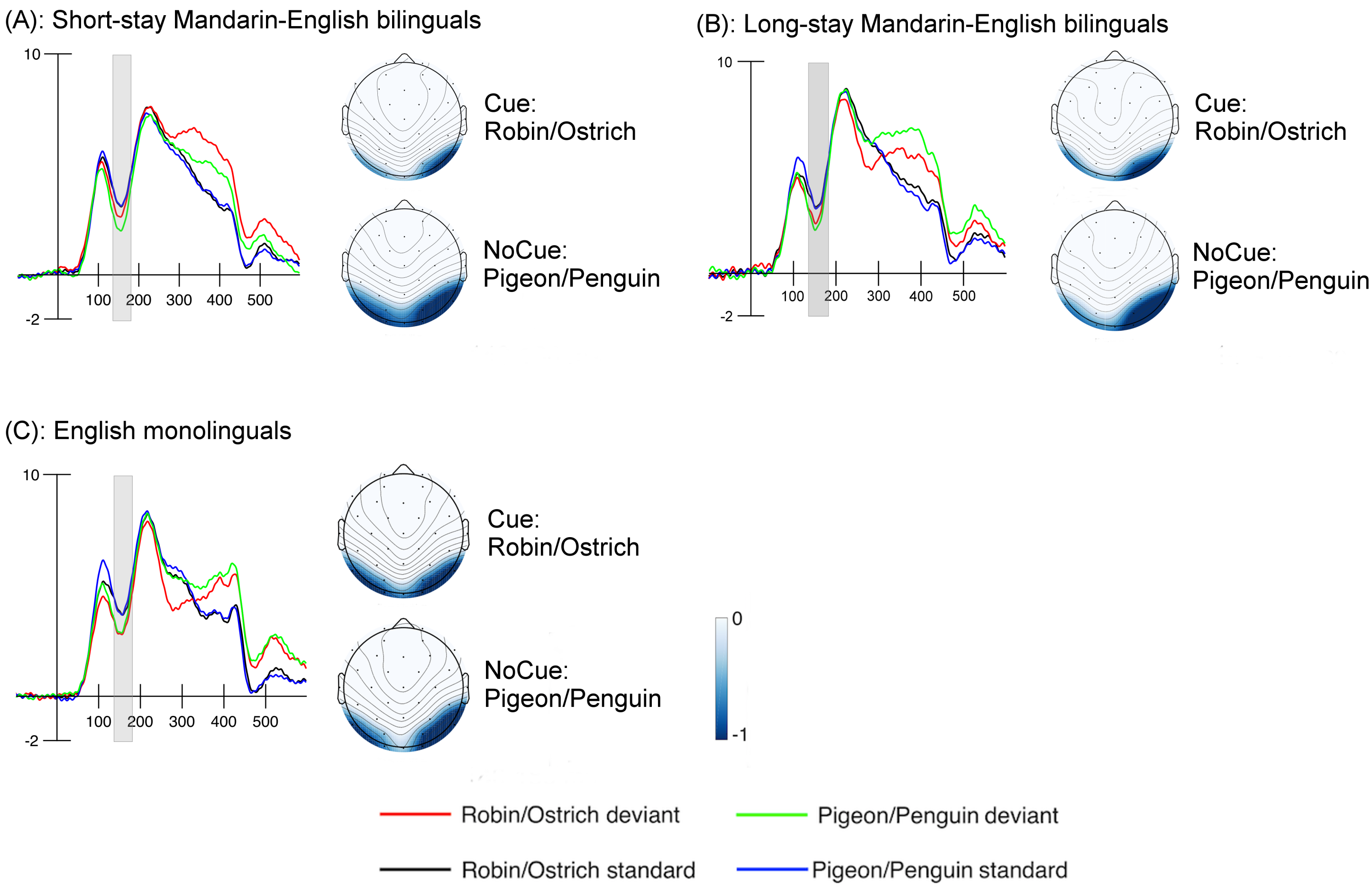

Figure 3.3. Grand average waveforms in microvolts (μV) to standards and deviants elicited by Robin/Ostrich and Pigeon/Penguin pairs for (A) Short-stay Chinese-English bilinguals, (B) Long-stay Chinese-English bilinguals, and (C) English monolinguals. Voltage maps of the vMMN effect (deviants-standards). Waveforms correspond to mean responses of electrodes PO3, PO4, O1, Oz, and O2. Note that negative is plotted down.

3.3.1 N1/vMMN (140-180 ms)

In the first set of analyses, mean amplitude of standard and deviant responses between 140 to 180 ms from short-stay bilinguals and English monolinguals were analyzed with LME models. Model 13 was fitted with Trial Type (Standard vs. Deviant, sum coded), Word Type (Cue vs. NoCue, sum coded), and Participant Group (English vs. Short-stay Bilingual, sum coded) as fixed effects, participants as random intercepts, and by-participant random slopes for the effects of Trial Type and Word Type (without interaction). Results of the tests evaluating the fixed effects included in the model are presented in Table 3.1.

Table 3.1.

Analysis of Variance Table for Model 13 (vMMN in short-stay bilinguals and English monolinguals).

	χ^2	*df*	*p*
Trial Type	54.44	1	< .001 ***
Word Type	0.31	1	*ns*
Participant Group	0.79	1	*ns*
Trial Type x Word Type	2.31	1	*ns*
Trial Type x Participant Group	0.16	1	*ns*
Word Type x Participant Group	2.45	1	*ns*
Trial Type x Word Type x Participant Group	4.18	1	.04 *

There was a significant main effect of Trial Type ($p < .001$). Deviant images elicited a more negative N1 than standard images. Importantly, there was a significant three-way interaction of Trial Type, Word Type, and Participant Group ($p = .04$). Separate analyses on each language group revealed that the Trial Type x Word Type interaction was significant for short-stay bilinguals, $\chi^2(1) = 7.54$, $p = .006$, but not for monolinguals, $\chi^2(1) = 0.11$. The vMMN effect was smaller for the *robin/ostrich* (cue) pair than the *pigeon/penguin* (no cue) pair in short-stay bilinguals, but the vMMN effect did not differ for the *pigeon/penguin* pair and *robin/ostrich* pair in English monolinguals. Likelihood ratio tests were conducted to measure the effect size of the three-way interaction. AIC of the full model with the triple interaction and the reduced model without the interaction was compared. A relative likelihood of 2.96 was found, indicating that the full model was 2.96 times more likely than the reduced model to minimize information loss.

In the second set of analyses, mean amplitude of standard and deviant responses between 140 to 180 ms from long-stay bilinguals and English monolinguals were analyzed with LME models. Model 14 was fitted with Trial Type (Standard vs. Deviant, sum coded), Word Type (Cue vs. NoCue, sum coded), and Participant Group (English vs. Long-stay Bilingual, sum coded) as fixed effects, participants as random intercepts, and by-participant random slopes for the effects of Trial Type and Word Type (without interaction). Results of the tests evaluating the fixed effects included in the model are presented in Table 3.2.

Table 3.2.

Analysis of Variance Table for Model 14 (vMMN in long-stay bilinguals and English monolinguals).

	χ^2	*df*	*p*
Trial Type	23.51	1	< .001 ***
Word Type	0.07	1	*ns*
Participant Group	0.50	1	*ns*
Trial Type x Word Type	0.03	1	*ns*
Trial Type x Participant Group	0.33	1	*ns*
Word Type x Participant Group	0.31	1	*ns*
Trial Type x Word Type x Participant Group	0.37	1	*ns*

There was a significant main effect of Trial Type ($p < .001$). Deviant images elicited a more negative N1 than standard images. No other main effects or interactions reached significance. The three-way interaction did not reach significance ($p > .50$), suggesting that long-stay bilinguals treated the difference between *robin/ostrich* deviants and standards similarly to that between *pigeon/penguin* deviants and standards, resembling the English monolinguals.

3.3.2 P1 (100-140 ms, Standards only)

To test for any potential perceptual differences in the two pairs of stimuli, mean amplitudes of the P1 evoked just by standard stimuli were analyzed in LME models. In the first set of analyses, mean amplitude of standard responses between 100 to 140 ms from short-stay bilinguals and English monolinguals were analyzed. Model 15 was fitted with Word Type (Cue vs. NoCue, sum coded), Stimulus Type (Typical vs. Atypical, sum coded), and Participant Group (Short-stay Bilingual vs. English, sum coded) as fixed effects, and participants as random intercepts. Results of the tests evaluating the fixed effects included in the model are presented in Table 3.3.

Table 3.3.

Analysis of Variance Table for Model 15 (P1 mean amplitudes, standards only in short-stay bilinguals and English monolinguals).

	χ^2	*df*	*p*
Stimulus Type	15.36	1	< .001 ***
Word Type	7.20	1	.007 **
Participant Group	0.19	1	*ns*
Stimulus Type x Word Type	15.59	1	< .001 ***
Stimulus Type x Participant Group	15.93	1	< .001 ***
Word Type x Participant Group	1.81	1	*ns*
Stimulus Type x Word Type x Participant Group	0.54	1	*ns*

There was a significant main effect of Word Type ($p = .007$), and a significant main effect of Stimulus Type ($p < .001$). Participants' visual system responded with a larger P1 to standard stimuli without a category cue in their Chinese name (*pigeon* and *penguin*) than to standard stimuli with category cue (*robin* and *ostrich*), and with a larger P1 to atypical items than typical items. There was also a significant two-way interaction between Word Type and Stimulus Type ($p < .001$), suggesting that there were some low-level perceptual visual differences between robin and ostrich vs. pigeon and penguin. Most importantly, the three-way interaction between Word Type, Stimulus Type, and

Participant Group was not significant ($p > .40$), suggesting that the low-level perceptual visual differences between robin and ostrich vs. pigeon and penguin was not significantly different for two language groups.

In the second set of analyses, mean amplitude of standard responses between 100 to 140 ms from long-stay bilinguals and English monolinguals were analyzed. Model 16 was fitted with Word Type (Cue vs. NoCue, sum coded), Stimulus Type (Typical vs. Atypical, sum coded), and Participant Group (Long-stay Bilingual vs. English, sum coded) as fixed effects, and participants as random intercepts. Results of the tests evaluating the fixed effects included in the model are presented in Table 3.4.

Table 3.4.

Analysis of Variance Table for Model 16 (P1 mean amplitudes, standards only in long-stay bilinguals and English monolinguals).

	χ^2	*df*	*p*
Stimulus Type	15.18	1	< .001 ***
Word Type	6.98	1	.008 **
Participant Group	0.71	1	*ns*
Stimulus Type x Word Type	9.95	1	.001 **
Stimulus Type x Participant Group	10.55	1	.001 **
Word Type x Participant Group	0.99	1	*ns*
Stimulus Type x Word Type x Participant Group	0.06	1	*ns*

There was a significant main effect of Word Type ($p = .008$), and a significant main effect of Stimulus Type ($p < .001$). Participants' visual system responded with a larger P1 to standard stimuli without a category cue in their Chinese name (*pigeon* and *penguin*) than to standard stimuli with category cue (*robin* and *ostrich*), and with a larger P1 to atypical items than typical items. There was also a significant two-way interaction between Word Type and Stimulus Type ($p = .001$), suggesting that there were some low-level perceptual visual differences between robin and ostrich vs. pigeon and penguin. Most importantly, the three-way interaction between Word Type, Stimulus Type, and

Participant Group was not significant (*p* > .70), suggesting that the low-level perceptual visual differences between robin and ostrich vs. pigeon and penguin was not significantly different for two language groups.

To sum up the results, short-stay bilinguals and English monolinguals showed a differential vMMN response pattern. The vMMN effects were significantly smaller for typical and atypical exemplars sharing a category level cue (*robin* and *ostrich*) than exemplars did not (*pigeon* and *penguin*) in short-stay bilinguals, but were not significant different for the two exemplar types in English monolinguals. These results indicate that short-stay bilinguals were less surprised by the deviant when it shared a category level cue in its Chinese name with the standard than when it did not, while English monolinguals showed no such difference because the category level cue did not exist in English. These results provide clear evidence that verbal labels influence object perception. Typical and atypical exemplars sharing a category level cue in their names were more perceptually similar in short-stay bilinguals than in English monolinguals. On the other hand, long-stay bilinguals and English monolinguals showed a similar vMMN response pattern. The vMMN effects showed no difference for the *pigeon/penguin* pair and *robin/ostrich* pair in long-stay bilinguals and English monolinguals, suggesting that the two groups perceived the differences between robin and ostrich vs. pigeon and penguin similarly.

3.4 Discussion

The goal of the current study was to explore the effects of word structure on object perception. In the current study, I tested the label-feedback hypothesis and investigated the effects of Chinese word structure on Chinese-English bilinguals' object perception with ERPs. In the current study, a visual oddball detection task revealed that short-stay Chinese-English bilinguals perceived typical and atypical exemplars of a category more similarly if they share a category cue in their Chinese names than exemplars that do not share a cue. On the other hand, English monolinguals and long-stay bilinguals did not show such a difference.

In the ERP data, the vMMN appeared in the same early window (140-180 ms) and in the same scalp location (posterior) as in previous studies investigating the vMMN effects (e.g., Boutonnet et al., 2013; Jouravlev et al., 2018). Boutonnet et al. (2013) suggested that these characteristics indicate that the vMMN reflects automatic, preattentional and prelexical processing. Deviant stimuli elicited a more negative vMMN than standard stimuli in both groups of bilinguals and English monolinguals, consistent with previous studies (Athanasopoulos et al., 2010). The vMMN has been broadly used as an index of perceived difference/similarity between objects. The early timing of the vMMN component is one reason that it is believed to only reflect perceptual processes; lexical access is not likely to have occurred at this early time window. Several previous studies have suggested that the earliest effects of lexical information become available at around 200 ms after stimulus onset in picture naming (Costa et al., 2009; Indefrey & Levelt, 2004; Strijkers et al., 2010) and even later in tasks with pictures that do not require naming (Strijkers, Holcomb, & Costa, 2011). The oddball detection task used in the current study did not require naming or any processing of images that were not targets. Therefore, the vMMN component observed in the current study likely reflects the perceptual processing of objects, but not any linguistic processes.

When the vMMN effects in short-stay bilinguals and English monolinguals were compared, the vMMN effects (deviants elicited a more negative vMMN than standards) were smaller for the *robin/ostrich* pair (which share a category cue in their Chinese names) than *pigeon/penguin* pair (which do not share a category cue) in short-stay bilinguals, while English monolinguals showed no such difference. These findings indicate that short-stay bilinguals perceived the *robin/ostrich* pair more similarly than *pigeon/penguin* pair. Sharing a category cue in two objects' L1 names made short-stay bilinguals perceive them more similarly than two objects do not share a category cue.

The current findings can be understand by two different explanations based on the label-feedback hypothesis (Lupyan, 2008, 2012). In the oddball detection task, participants passively viewed a series of pictures, and made responses only to the targets, while of interest were their brain responses to the "distractor" pictures. Based on the label-feedback hypothesis, participants' ongoing perceptual processes could be influenced by the feedback from the on-line activation of the object label when they are doing the task. More specifically, in the oddball detection task, a sequence of frequently presented penguin standards would have activated the label *penguin*, and the label would have then activated a range of perceptual features of a penguin, like can swim, cannot fly, eats fish, etc. When the pigeon deviant was presented, the picture would have activated perceptual features of a pigeon, like has wings, can fly, has feathers, etc. Because penguin is an atypical bird and pigeon is a typical bird, the perceptual features that were activated by feedback from the label for the penguin standard would have had less overlap with the perceptual features that were activated by the pigeon picture, thus producing a large vMMN effect. Similarly, a sequence of frequently presented ostrich standards would have activated the label *ostrich*, and the label would have then activated a range of perceptual features of an ostrich, like has wings, has feathers, cannot fly, etc. In addition, an ostrich's Chinese name has the category cue *bird* embedded, which would have made the most diagnostic features of the category bird (e.g., has wings, has feathers) activated to a higher degree than the non-diagnostic features (e.g., cannot fly). When the robin deviant was presented, the picture would have activated a range of perceptual features of a robin, like has wings, red belly, has feathers, etc. As a result, the relevant features activated from the feedback from the Chinese label for the ostrich would be highly overlapped with the features activated for the robin, thus producing a reduced vMMN effect.

Similar to Experiment 1 and 2, there is another alternative way to understand the current findings based on the label-feedback hypothesis. Bilingual participants' organization of the conceptual representations of four birds: robin, ostrich, pigeon, and penguin could have been changed under the long-term influence of the feedback from daily usage of the birds' Chinese labels. Robin and ostrich become more strongly associated with the most diagnostic features of the category bird through the feedback from the category cue in their Chinese names, resulting in them being be stored closer together in the center of the category. On the contrary, atypical birds that do not have a category cue in their Chinese names (e.g., penguin) are stored in the periphery of the category bird, while typical birds without a cue (e.g., pigeon) are stored closer to the center of the category, because the diagnostic features of the category are more salient for typical members than atypical members. In the oddball detection task, bilingual participants would have produced a smaller surprise when they saw an ostrich deviant followed by robin standards than when they saw a penguin deviant followed by pigeon standards, because robin and ostrich were stored closer together in the semantic space than pigeon and penguin. As a result, *robin/ostrich* pair were perceived more similarly to each other than *pigeon/penguin* pair in bilinguals, thus producing a reduced vMMN effect.

In Chapter 2, I discussed the possibility that the faciliatory effects observed in the categorization tasks were simply due to the lexical overlap between category labels and object names. The reduced typicality effects for objects with category cues in their Chinese names in late ERP components (ELC and N400) demonstrated that the effects observed in Chapter 2 are unlikely due only to the overlap at the lexical level, instead, I believed that these effects involved feedback from verbal labels to semantic representations. In the current study, my argument on this issue was further reinforced with the oddball detection task. The faciliatory effects of a category cue was observed in an early time window between 140 to 180 ms. As aforementioned, it is believed that lexical information is not likely to be available at this early time window (e.g., Boutonnet et al., 2013; Jouravlev et al., 2018), which further demonstrated that the current findings were unlikely due only to lexical overlap.

In addition, the difference observed between *robin/ostrich* pair and *pigeon/penguin* pair in short-stay bilinguals is very unlikely to be due to some low level perceptual differences between two stimulus pairs. In the current study, I used a design in which stimuli that were used as deviants in one block were used as standards in another, and vice versa, and then averaged across the two blocks. This ensured that within each word type (Cue vs. NoCue) condition, standard and deviant stimuli were exactly matched. In addition, P1 responses to standards were examined, and no significant interaction between Word Type, Stimulus Type, and Participant Group was observed. This means that the perceptual difference when switching from standard to deviant in the Cue vs NoCue conditions was the same for bilingual groups and English monolingual group.

On the other hand, when comparing the vMMN effects in long-stay bilinguals and English monolinguals, no difference was found for the *robin/ostrich* pair and *pigeon/penguin* pair in both bilinguals and English monolinguals. Long-stay bilinguals and English monolinguals perceived the differences between *robin* and *ostrich* vs. *pigeon* and *penguin* similarly. These findings are consistent with Athanasopoulos et al.'s study (2010), in which no differences were found between long-stay Greek-English bilinguals and English monolinguals in perceiving shades of light/dark blue, and further demonstrated that as bilinguals stay in an L2-speaking country for a longer time, the influences from their L1 on object perception gradually diminish. Athanasopoulos et al. argued that this effect of length of stay in the L2 country is likely to be fundamentally a matter of use of language. The more bilinguals stay in the L2 country, the less opportunity they have to use their L1 words to refer to objects. In the current study, as Chinese-English bilinguals live in Canada for a longer time, they have less opportunity to use Mandarin Chinese. The category information embedded in an object's Chinese name gets activated either less often or to a lesser degree than Chinese monolinguals or bilinguals who have stayed in Canada for a shorter time.

Therefore, based on the on-line influence of labels account, in the oddball detection task, when a sequence of ostrich standards was presented to a long-stay bilingual, the English label *ostrich* would be activated to a higher degree than the Chinese label *鸵鸟*. This would result in the long-stay bilinguals getting more feedback from the English label *ostrich* to the perceptual level than the Chinese label. Because the English label *ostrich* does not have the category cue *bird* embedded in it, long-stay bilinguals get little boost in activation of the most diagnostic features of the category bird when they saw the ostrich standards. When the robin deviant was presented, the picture would have activated perceptual features of a robin. As a result, the relevant features activated for an ostrich would have little overlap with the features activated for a robin, thus producing a large vMMN difference between *robin/ostrich* standards and deviants. Alternatively, long-stay bilinguals' organization of the conceptual representations of four birds: *robin*, *ostrich*, *pigeon*, and *penguin* could have changed under the influence of the relatively large amounts of English usage. Because the English label *ostrich* does not have the category cue *bird* embedded in it, long-stay bilinguals get little boost in activation from the most diagnostic features of the category bird when they use the English label. This would result in the strong association between ostrich and the most diagnostic features of the category being gradually weakened, and ostrich being pushed away from the center of the category. On the contrary, robin, as a typical bird, would still be represented close to the center of the category. As a result, long-stay bilinguals performed more like English monolinguals in the oddball detection task in that they showed similar vMMN effects for the *robin/ostrich* pair and *pigeon/penguin* pair.

The current results reinforced and extended previous findings that labels have an important role in object perception. The current results were consistent with previous studies using a visual oddball paradigm within one language (Jouravlev et al., 2018; Maier et al., 2014) and with two different languages (Boutonnet et al., 2013; Thierry et al., 2009). In these studies, two objects sharing a common label were perceived more similarly than objects having different labels. The current results further suggest that two objects can also be perceived more similarly if they share a category cue in their names (robin/ostrich) compared to objects that do not share a cue (pigeon/penguin). In addition, the current results were consistent with Athanasopoulos et al.'s study (2010) that used a visual oddball paradigm with bilingual groups. By testing bilinguals that had lived in an L2 country for different amounts of time, Athanasopoulos et al. found that as bilinguals live in an L2 country for a longer time, they become less sensitive to the distinctions between objects that do not share a label in their L1 names. To my knowledge, this is the only study that used a visual oddball paradigm to investigate the development of the influences from verbal labels on object perception in bilinguals. The current findings further confirmed Athanasopoulos et al.'s findings that as bilinguals live in an L2-speaking country for a longer time, the influences from bilinguals' L1 on their object perception gradually attenuate. Together with these previous studies, the current findings also demonstrated that the visual oddball paradigm is a useful and reliable technique to investigate the effects of verbal labels on object perception. By measuring the vMMN effects, we can have a look into the role of verbal labels in the automatic and preattentional perceptual processes in both monolinguals and bilinguals.

In conclusion, the current study provides compelling evidence that word structure influences object perception. Two main findings were observed. First, sharing a category cue in two objects' L1 names made bilinguals perceive them more similarly than two objects do not share a category cue. Second, the influences of L1 word structure on object perception diminish as bilinguals live in the L2 country for a longer time. These findings provide supporting evidence for the label-feedback hypothesis which states that the effects of labels can penetrate perceptual processes and influence object perception. One limitation of the current study is that bilingual participants were grouped only based on the amount of time they have lived in the L2 country. However, the amount of time living in an L2-speaking country could be intertwined with the amount of exposure to L2, or L2 proficiency. Future studies could try to disentangle these factors and examine their influences on bilingual object perception separately.

3.5 References

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4 General Discussion

The linguistic relativity hypothesis (LRH) states that the language(s) one speaks shapes the way one thinks (e.g., Whorf, 1940, 1956). This hypothesis has been controversial, largely because it was erroneously equated by some researchers with linguistic determinism (see Pavlenko, 2014). More recently, researchers have focused on uncovering ways in which the properties of the language we speak influence our thought. Many studies have provided support for the LRH in various domains of human cognition, like visual perception (e.g., Thierry, Athanasopoulos, Wiggett, Dering, & Kuipers, 2009), object categorization (e.g., Lupyan & Casasanto, 2015), and event conceptualization (e.g., Li, Jones, & Thierry, 2018). In an important advance to the field, Lupyan (2012) proposed a mechanism to explain how language could influence thought. The label-feedback hypothesis assumes that a word label is not simply a means of accessing a concept, but it can provide top-down feedback to the level of conceptual representations and perception, thus affecting the representation and perception of the concept. The activation of an object's verbal label results in the activation of the most typical or diagnostic features of the category, drawing category members that share those features closer together and pushing non-members away. This hypothesis has been supported by studies that have shown that verbal labels facilitate category learning and categorization processes (e.g., Edmiston & Lupyan, 2015; Lupyan & Casasanto, 2015; Lupyan & Thompson-Schill, 2012); two objects are perceived as more similar when they share a verbal label than they do not share a label (e.g., Boutonnet, Dering, Viñas-Guasch, & Thierry, 2013; Jouravlev, Taikh, & Jared, 2018; Thierry et al., 2009).

The label-feedback hypothesis not only provides a new perspective on the language-thought interaction, but it can also provide some insights into the complexity of language-thought interaction in bilinguals. Many bilingual mental models have proposed that bilinguals have two separate lexical stores, and further, that the links between word labels and concepts can be complex in bilinguals. For example, the Distributed Conceptual Feature (DCF) model (De Groot, 1992) proposes that a bilingual's two labels for the same concept could be linked to somewhat different sets of semantic features;

each label could have some language-specific features that are not shared by the other label. The Shared (Distributed) Asymmetrical (SDA) model (Dong et al., 2005) proposes that as a bilingual's L2 proficiency changes, the strengths of the links between word labels and semantic features change as well. According to the label-feedback hypothesis, word labels can send feedback to conceptual representations, thus affecting the representation and perception of the concept. Since bilinguals have two labels for each concept, and the strengths of the links between labels and the concept can change over time, the feedback from labels to the conceptual level could be highly complicated and not as stable as that in monolinguals. In addition, as the Bilingual Interactive Activation Plus Model (BIA+; Dijkstra & Van Heuven, 2002) suggests that lexical activation in bilinguals is non-selective, a label in one language could potentially influence a bilingual's cognitive processes in the other language.

Although there is much supporting evidence for the LRH and the label-feedback hypothesis, most of the studies focused on monolingual groups. Several studies that have either compared monolingual speakers of different languages (e.g., Boutonnet et al., 2013; Thierry et al., 2009) or compared bilinguals to monolinguals (e.g., Athanasopoulos, 2009; Athanasopoulos, Dering, Wiggett, Kuipers, & Thierry, 2010) have focused on translation ambiguous words, that is, words that have one label in one of the languages (e.g., Spanish *taza*) but two in the other language (English *cup* and *mug*). Liu et al. (2010) pointed out an interesting aspect of Chinese words that could also influence object categorization. In Mandarin Chinese, most nouns provide explicit category information morphologically, like the English word *sunflower,* which has the category cue *flower* embedded in it. Liu et al. investigated the influence of this category information in an object's Chinese name on categorization processes. Results demonstrated that the category information facilitated the categorization of pictures in Chinese speakers and reduced the influence of typicality. These results provided some evidence that word structure can influence object categorization. However, there were several limitations to Liu et al.'s study. First, no exemplars without a category cue in their Chinese names were included for comparison. Second, the number of stimuli was limited, especially for an ERP study. Third, they compared Chinese and English monolinguals but did not study bilinguals.

Inspired by Liu et al.'s (2010) study, in the current research, I further explored the effects of Chinese word structure on object categorization and perception. Objects that do not have a category cue in their Chinese names were added to the experimental stimuli, and the number of stimuli was increased compared to their study. Instead of Chinese monolinguals, Chinese-English bilinguals were tested and compared to English monolinguals. The ERP experiments examined the impact of having the category clue in one of their languages (Chinese) but not the other (English). Of particular interest was whether there was an influence of the category cue in the Chinese name when participants completed categorization tasks in English or in the oddball task where language is not needed. That is, I sought to determine whether a bilingual's object categorization and perception are constantly under the influence from his/her two languages even when only one language is being used and no clue shows that the other language is relevant. I used the label-feedback hypothesis as a guiding framework to help understand how the category cue in the Chinese name could influence categorization and perception.

4.1 Summary of the Current Findings

In Chapter 2, Experiment 1, participants categorized pictured typical and atypical objects, in Chinese in one session and in English in another. Results were consistent with the findings of Liu et al. that Chinese speakers showed a reduced typicality effect compared to English speakers when categorizing pictured objects that have a category cue in their Chinese names. The category information in an object's Chinese name facilitated categorization of the object, thus reducing the influence of typicality. Interestingly, in the current research, this facilitation was also observed when bilingual participants did the task in English and there was no evidence that Chinese was required, providing evidence of feedback from Chinese words even when the language was not actively in use. In Experiment 1, the number of experimental stimuli was limited because of low name agreement for some pictures, so each stimulus was presented twice in the task. Results showed that the repeated representation influenced participants' performance; repeating items a second time attenuated critical findings. Therefore, in

Experiment 2, participants categorized English words instead of pictures. Results further suggested that the category information in an object's L1 name facilitated categorization of objects in bilinguals, and this facilitation existed even when bilinguals were put into an L2-speaking environment where no clue indicated that L1 was involved. The findings in Chapter 2 demonstrated that Chinese word structure has an important influence on bilinguals' categorization processes. In Chapter 3, I further investigated the effects of labels on object perception with a visual oddball detection paradigm where no verbal processing was involved. Participants detected a target picture in a series of rapidly presented pictures, and no language was needed in the task. Results showed that the influence of labels can penetrate non-verbal processes; objects that share a category cue in their L1 names were perceived more similarly by bilinguals than two objects do not share a category cue. However, this effect was only found in bilinguals who have lived in an L2-speaking country for a short period of time; long-stay bilinguals showed no such influence from objects' L1 names.

These findings extend our understanding of language-thought interactions. The findings from the Chinese session in Experiment 1 are consistent with previous studies investigating the effects of verbal labels on object categorization that have found that labels are helpful in categorizing both novel and familiar objects (e.g., Casasola, 2005; Edmiston & Lupyan, 2015; Fulkerson & Waxman, 2007; Lupyan & Casasanto, 2015), and that labels can selectively activate the most diagnostic features of a category (e.g., Boutonnet & Lupyan, 2015; Gervits, Johanson, & Papafragou, 2016; Lupyan & Thompson-Schill, 2012). The current research further extended this work to bilingual groups, and in particular, demonstrated that characteristics of a label in one language influenced object categorization in the other language. The results provided evidence that the effects of verbal labels on object categorization are more complex in bilinguals than in monolinguals, because bilinguals have two labels for each concept and their two languages are active simultaneously. Furthermore, previous research had provided evidence that object categorization is influenced by whether or not an object has a label (e.g., Edmiston & Lupyan, 2015; Lupyan, Rakison, & McClelland, 2007), and here it was demonstrated that specific characteristics of the label can also influence categorization.

The findings in Chapter 3 are consistent with previous studies investigating the effects of verbal labels on object perception with a visual oddball detection paradigm (e.g., Boutonnet et al., 2013; Jouravlev et al., 2018). Previous research had provided evidence that object perception is influenced by whether or not two objects share a common label (e.g., Boutonnet et al., 2013; Jouravlev et al., 2018; Thierry et al., 2009), and here it was demonstrated that specific characteristics of the label, like whether or not two objects share a category cue, can also influence perception. The current research further extended this work to bilingual groups, and in particular examined whether exposure time to an L2 environment affects the strength of feedback from bilinguals' L1 on perception. The results were consistent with Athanasopoulos et al.'s (2010) findings and further provided evidence that as bilinguals live in an L2-speaking country for a longer time, the influences from bilinguals' L1 on their object perception attenuate.

One interesting finding in the current research is that the bilinguals tested in Chapter 2, who were long-stay bilinguals, showed an influence of L1 in a categorization task in which all stimuli were presented in English, while comparable participants in Chapter 3 performed like English monolinguals in an oddball detection task. One possible reason for this is the different processing levels that are involved in the two tasks. A categorization task involves more extensive semantic processing than an oddball detection task, which mainly involves perceptual processing. The feedback from labels to the perceptual features might be stronger in cognitive processes that involve verbal processing than non-verbal processes. In addition, the ERP results in Chapter 2, Experiment 1 showed that the effects of Chinese on bilinguals' categorization processes were not evident until the 375-500 ms time window, suggesting that long-stay bilinguals' L1 could be activated slowly when they are doing an L2 task. This slow processing might be only picked up in the categorization task which involves extensive verbal processing.

4.2 Theoretical Implications

The findings of the current research have implications both for the label-feedback hypothesis and for theories of bilingual language processing. The results provide supporting evidence for the label-feedback hypothesis that the activation of an object's verbal label can send feedback to perceptual features associated with the label, especially the most diagnostic features of the object category, and thus modulate conceptual representations and visual perception. More specifically, the current results suggest that the category information embedded in a verbal label could boost the activation of the most diagnostic features of the category, and strongly direct attentional focus to the object's prototypical features. The feedback from verbal labels is not restricted to cognitive processes that involve verbal processing, but can penetrate non-verbal processes as well. In addition, the label-feedback hypothesis only considered the influence of having a verbal label for an object on object categorization and perception. Based on the current findings, the hypothesis needs to further take into account the different characteristics of labels, like the structure of a label.

The current findings can be accounted by the label-feedback hypothesis which assumes that the feedback from labels produce a transient "perceptual warping" in the ongoing processes of object categorization and perception. However, findings in the current research can also be explained by long-term effects of language in which the organization of category representations are changed through the feedback from every day usage of labels. In Lupyan's original papers where the label-feedback hypothesis was proposed (Lupyan, 2008, 2012), he argued several times that the activation of a label affects perceptual processing in a transient, on-line manner. However, while both of the accounts are based on the label-feedback hypothesis, I am more in favor of the second one. Various studies investigating naming patterns of objects in bilinguals and monolinguals have suggested that the organization of category members and category boundaries in bilinguals are different from either of the monolingual counterparts under the long-term influence of bilinguals' two languages (Ameel, Malt, Storms, & Van Assche, 2009; Ameel, Storms, Malt, & Sloman, 2005; Malt, Li, Pavlenko, Zhu, & Ameel, 2015; Malt & Sloman, 2003; Pavlenko & Malt, 2011). In addtion, compared to Experiment 1, the stronger faciliatory effects of category cue observed in Experiment 2 suggest that the feedback of verbal labels could have influenced the semantic space both temporarily and permanently. In Experiment 2, with the object labels presented in the categorization task, the categorization processes could have been influenced by both the short-term feedback from the activated labels, and the long-term effects of daily usage of labels. As a result, stronger effects were observed than Experiment 1, in which no object labels were presented in the categorization task. Therefore, the label-feedback hypothesis needs to further take into account the long-term influences of the feedback from verbal labels on the organization of conceptual representations.

The current findings also provide some insights into the language-thought interaction in bilinguals and bilingual mental models. Bilinguals have two labels for each object, which makes the influence from label feedback in bilinguals more complex than in monolinguals. The findings in Chapter 2 suggest that when a bilingual is using only one of his/her languages, characteristics of the labels in the other language still have an influence on the ongoing cognitive processing. Even when there is no clue showing that the other language is involved in the current task, the label in the other language still can get activated and send feedback activation to the perceptual features that are associated with it, thus influencing processing. The Bilingual Interactive Activation Plus Model (BIA+; Dijkstra & Van Heuven, 2002) can account for the parallel activation of bilinguals' two languages. The BIA+ model assumes that bilinguals' two languages share the same representations at sublexical levels, and the whole word representations for bilinguals' two languages are fully connected and interactive. Bilinguals' two languages are activated in parallel because of the shared representations and interconnectedness. However, the BIA+ model focuses on word recognition and includes little about how the activated information from the other language could influence the current semantic processing.

The findings in Chapter 3 suggest that language-thought interaction in bilinguals is a dynamic system that could be influenced by various factors, like the amount of time living in an L2-speaking country. The results in Chapter 3 showed that bilinguals who have stayed in an L2-speaking country for a long time (M = 4 years) lost the influence from their L1 when doing an oddball detection task. The results suggest that the extent and strength of the feedback from a verbal label to the perceptual level may be linked to the amount of usage of the label. The more a certain label is used in daily life, the stronger the association between the label and the perceptual features of the object. As a result, stronger feedback from the label would be sent to the perceptual level when it is activated. The BIA+ model, the Revised Hierarchical Model (RHM; Kroll & Stewart, 1994) and the Shared (Distributed) Asymmetrical (SDA) model (Dong et al., 2005) can account for the developmental aspects in the bilingual mind. For example, the RHM assumes that in low-proficiency bilinguals, the link between L2 words and the shared conceptual representations is weak. As bilinguals become more proficient in L2, the links between L2 words and the conceptual representations gradually strengthen. The BIA+ model also posits a quantitative difference in connection strength as a bilingual's L2 proficiency develops. This assumption can account for the findings that in Chapter 3, long-stay bilinguals showed a strong influence from their L2 when doing the oddball detection task. These models all assume bidirectional links between lexical and conceptual representations, and therefore in principle they could accommodate the label feedback mechanism. However, the BIA+ and RHM put aside the nature of conceptual representations; concepts are represented as a "black box". Consequently, it is difficult to form hypotheses about how lexical representations could influence semantic processing in these models. The Distributed Conceptual Feature model (De Groot, 1992) and the SDA model (Dong et al., 2005) assume that concepts are represented by features, as does the label-feedback hypothesis, and therefore these models could more readily accommodate the label feedback mechanism. However, neither of these theories considered how lexical representations might affect semantic representations. Therefore, there seems to be a great theoretical value to incorporate the label-feedback hypothesis into bilingual mental models. It would provide a more comprehensive theoretical framework for bilingual research and can help us better understand the language-thought interaction in bilinguals.

4.3 Limitations and Future Directions

One limitation of the current research is that no Chinese monolingual groups were included due to the difficulty in recruiting them in Canada. In Chapter 2, without including a Chinese monolingual group, we do not know whether Chinese monolinguals would show stronger faciliatory effects from the category information than bilinguals. Bilingual participants' knowledge of English might have weakened the influence from

Chinese labels. In Liu et al.'s study (2010), which inspired my study in Chapter 2, Chinese monolinguals showed the same response pattern in the categorization task as bilinguals did in the current research when they were tested in Chinese. This provides some insights into how Chinese monolinguals would perform in the current study, but further confirmation is needed. By comparing the performance of Chinese monolinguals and Chinese-English bilinguals, we can get some insights into how the experience of learning a second language changes the amount of influence from a bilingual's L1 on their categorization processes. In Chapter 3, Chinese-English bilinguals who had lived in Canada for a short period of time (less than one year) were tested. While I believe that the performance of these short-stay bilinguals should resemble Chinese monolinguals, because of their relatively low English proficiency and less immersion in English culture, we cannot rule out the possibility that their knowledge of English could have reduced the size of their vMMN effect in the oddball detection task. Therefore, Chinese monolinguals still need to be tested in future research to see if they would show stronger effects from the category information than bilinguals.

With regards to the effects of labels on object categorization and perception, the current research focused on questions of whether the category information embedded in an object's Chinese name would affect Chinese-English bilinguals' categorization and perception. Future research could further investigate this question in English-Chinese bilinguals. By testing English-Chinese bilinguals with various L2 proficiency levels and age of acquisition, we could get some insights about questions like whether second language learners of Chinese could make use of the newly acquired category cue in an object's name to help with categorization, and how long does it take for Chinese learners to be able to make use of the category information in objects' names.

One interesting implication of the current findings pertains to patients who suffer from semantic dementia (SD). Semantic dementia is a progressive disorder characterized by loss of semantic memory in both the verbal and non-verbal domains. Research with SD patients has suggested that SD patients tended to not only have general difficulties in picture naming, single word comprehension, and other tasks that require semantic memory, but also they overly rely on information that is "typical" of the category or knowledge base being tested (Rogers, Ralph, Hodges, & Patterson, 2004; Woollams, Cooper-Pye, Hodges, & Patterson, 2008). For example, Woollams et al. (2008) assessed picture naming data for 225 common objects from 78 SD patients. They found that aside from picture familiarity, frequency and semantic domain (living/non-living), the typicality of the object within its semantic category was an important factor that impacted naming accuracy. Patients named typical pictures with more accuracy. The over-reliance on typicality in SD patients is not only true for picture naming, but also for word recognition, as well as for nonsense words with typical and atypical spelling patterns (Rogers et al., 2004). An interesting question given the findings from the current research is whether Chinese patients with SD would also show typicality effects for all words, or whether the category information provided in Chinese nouns could be used to help ameliorate these symptoms.

Another question that could be investigated in future research is that whether the effects of word structure on conceptual representations and perception could be observed with other language pairs. The current study focused on Chinese and English because I am a Chinese-English bilingual. Other language pairs could have similar contrasts in how words are constructed, and this could be useful to test the effects of words structure on concepts and perception. One issue in the current research is that there are great cultural differences between China and Canada, which could result in different conceptual representations for the translation equivalent words. As the Distributed Conceptual Feature (DCF) model (De Groot, 1992) and the Shared (Distributed) Asymmetrical (SDA) model (Dong et al., 2005) suggested that there could be some features for a concept that are specific to one language. Although in the current research, only objects that are looked alike in China and Canada were used as stimuli, there could still be some differences between Chinese culture and Canadian culture regarding to the situations in which the objects are typically encountered or the ways in which they are used. For example, daffodils are typically only seen in summer time in Canada, while in China, daffodils are often raised indoors in winter time to celebrate the new year. These cultural-specific features might have attenuated the influences of the L1 labels in the current research. Therefore, future research could try to manipulate the conceptual similarity within a language pair. By comparing concepts that have very similar features across the languages and concepts that have quite different features, we can further investigate if the cross-language feedback effects found in the current research would be moderated by conceptual similarity across languages. Finally, the current research focused on the effects of word structure on bilingual's object categorization and perception. Further studies investigating language-thought interaction could go beyond the effects of labels and characteristics of labels, and pay more attention to the structural influences brought on by linguistic features such as grammar and syntax (e.g., grammatical gender) on bilingual's cognitive processes.

4.4 Conclusions

This dissertation provides supporting evidence for the linguistic relativity hypothesis (LRH) which states that the language(s) one speaks influences thought. The current research focused on word labels and further demonstrated that labels have an important effect on object categorization and perception. Furthermore, the current research extended the work to bilinguals and suggests that the language-thought interaction is more complex in bilinguals than in monolinguals. Bilinguals' two languages are active in parallel, thus their cognitive processes are constantly under the influence of two sets of labels, even when only one language is being used. In the current research, an interesting characteristic of Chinese labels was used, and the results demonstrated that categorization and perception of an object are not only influenced by whether or not it has a verbal label, but they are also influenced by how a verbal label is constructed. The current research also provides supporting evidence for the label-feedback hypothesis from a new perspective by focusing on the structure of labels. The label-feedback hypothesis provides a useful framework in which to understand the mechanisms of language-thought interactions in bilinguals.

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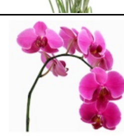
Appendices

Appendix A

List of Critical Stimuli in Experiment 1, Chapter 2.

	Category label		Item	Typicality rating	Name & Naming agreement (%)		Condition
	English	Mandarin			English	Mandarin	
1	VEHICLE	车		98.26	car (66)	汽车/轿车 (43/43)	CueTyp
2	VEHICLE	车		58.7	train (100)	火车 (93)	CueAtyp
3	VEHICLE	车		85.58	bus (100)	巴士 (31)	NoCueTyp
4	VEHICLE	车		43.23	tank (98)	坦克 (100)	NoCueAtyp
5	FLOWER	花		87.73	daffodil (32)	水仙花 (31)	CueTyp
6	FLOWER	花		66.26	chrysanthemum (N/A)	菊花 (71)	CueAtyp
7	FLOWER	花		91.32	daisy (60)	雏菊 (45)	NoCueTyp
8	FLOWER	花		61.47	lavender (44)	薰衣草 (91)	NoCueAtyp
9	FLOWER	花		85.23	orchid (35)	兰花 (15)	CueTyp
10	FLOWER	花		70.11	lotus (51)	莲花/荷花 (52/43)	CueAtyp

11	FLOWER	花		93.70	tulip (65)	郁金香 (65)	NoCueTyp
12	FLOWER	花		51.76	dandelion (55)	蒲公英 (45)	NoCueAtyp
13	TREE	树		92.64	maple (56)	枫树 (54)	CueTyp
14	TREE	树		82.67	willow (61)	柳树 (78)	CueAtyp
15	TREE	树		88.14	spruce (56)	雪松 (63)	NoCueTyp
16	TREE	树		56.02	bamboo (89)	竹子 (100)	NoCueAtyp
17	SEA ANIMAL	海洋生物		93.41	dolphin (100)	海豚 (95)	CueTyp
18	SEA ANIMAL	海洋生物		60.73	urchin (62)	海胆 (89)	CueAtyp
19	SEA ANIMAL	海洋生物		94.70	whale (93)	鲸鱼 (69)	NoCueTyp
20	SEA ANIMAL	海洋生物		60.55	clam (58)	蛤蜊 (54)	NoCueAtyp
21	SEA ANIMAL	海洋生物		84.23	turtle (98)	海龟 (80)	CueTyp
22	SEA ANIMAL	海洋生物		40.50	conch (31)	海螺 (82)	CueAtyp
23	SEA ANIMAL	海洋生物		93.85	shark (100)	鲨鱼 (100)	NoCueTyp
24	SEA ANIMAL	海洋生物		75.23	eel (N/A)	鳗鱼/黄鳝 (21/21)	NoCueAtyp

25	SEA ANIMAL	海洋生物		83.50	starfish (89)	海星 (100)	CueTyp
26	SEA ANIMAL	海洋生物		66.00	manatee (47)	海狮/海豹/海象 (30/19/19)	CueAtyp
27	SEA ANIMAL	海洋生物		85.41	octopus (93)	章鱼 (67)	NoCueTyp
28	SEA ANIMAL	海洋生物		66.47	oyster (56)	生蚝 (52)	NoCueAtyp
29	BIRD	鸟		90.41	robin (63)	知更鸟 (52)	CueTyp
30	BIRD	鸟		64.50	ostrich (85)	鸵鸟 (97)	CueAtyp
31	BIRD	鸟		93.52	pigeon (64)	鸽子 (84)	NoCueTyp
32	BIRD	鸟		54.26	penguin (96)	企鹅 (100)	NoCueAtyp
33	BIRD	鸟		83.02	woodpecker (67)	啄木鸟 (89)	CueTyp
34	BIRD	鸟		68.73	flamingo (94)	火烈鸟 (73)	CueAtyp
35	BIRD	鸟		91.00	crow (96)	乌鸦 (82)	NoCueTyp
36	BIRD	鸟		68.61	peacock (89)	孔雀 (100)	NoCueAtyp
37	GEM	宝石		94.38	ruby (91)	红宝石 (76)	CueTyp
38	GEM	宝石		75.02	jade (31)	玉石 (43)	CueAtyp

39	GEM	宝石		89.92	emerald (69)	祖母绿 (10)	NoCueTyp
40	GEM	宝石		72.52	pearl (96)	珍珠 (95)	NoCueAtyp
41	GEM	宝石		91.32	diamond (96)	钻石 (97)	CueTyp
42	GEM	宝石		73.85	opal (35)	蛋白石/石头 (2/78)	CueAtyp
43	GEM	宝石		82.52	crystal (58)	紫水晶 (95)	NoCueTyp
44	GEM	宝石		67.08	quartz (40)	粉晶 (39)	NoCueAtyp
45	VEGETABLE	菜		93.79	lettuce (71)	生菜 (65)	CueTyp
46	VEGETABLE	菜		55.55	parsley (58)	香菜 (80)	CueAtyp
47	VEGETABLE	菜		95.79	carrot (98)	胡萝卜 (100)	NoCueTyp
48	VEGETABLE	菜		63.64	bean (85)	豆角/四季豆 (45/21)	NoCueAtyp
49	VEGETABLE	菜		87.73	celery (65)	芹菜 (86)	CueTyp
50	VEGETABLE	菜		60.38	bok choy (N/A)	白菜 (73)	CueAtyp
51	VEGETABLE	菜		92.26	cucumber (94)	黄瓜 (100)	NoCueTyp
52	VEGETABLE	菜		66.02	eggplant (89)	茄子 (100)	NoCueAtyp

53	VEGETABLE	菜		85.58	spinach (60)	菠菜 (65)	CueTyp
54	VEGETABLE	菜		68.76	beet (49)	甜菜根 (15)	CueAtyp
55	VEGETABLE	菜		83.50	peas (83)	豌豆 (73)	NoCueTyp
56	VEGETABLE	菜		75.38	potato (100)	土豆 (93)	NoCueAtyp
57	FRUIT	水果		98.64	apple (100)	苹果 (100)	CueTyp
58	FRUIT	水果		54.20	fig (36)	无花果 (43)	CueAtyp
59	FRUIT	水果		97.17	orange (100)	橙子/橘子 (67/28)	NoCueTyp
60	FRUIT	水果		50.97	coconut (100)	椰子 (93)	NoCueAtyp
61	FRUIT	水果		86.79	mango (82)	芒果 (100)	CueTyp
62	FRUIT	水果		45.61	avocado (76)	牛油果 (84)	CueAtyp
63	FRUIT	水果		95.50	banana (100)	香蕉 (100)	NoCueTyp
64	FRUIT	水果		62.76	apricot (77)	杏 (56)	NoCueAtyp
65	ALCOHOL	酒		94.67	beer (98)	啤酒 (95)	CueTyp
66	ALCOHOL	酒		79.35	cocktail (64)	鸡尾酒 (86)	CueAtyp

67	ALCOHOL	酒		96.67	vodka (87)	伏特加 (32)	NoCueTyp
68	ALCOHOL	酒		73.70	brandy (44)	白兰地 (31)	NoCueAtyp
69	ALCOHOL	酒		93.29	wine (100)	红酒 (84)	CueTyp
70	ALCOHOL	酒		82.23	gin (60)	琴酒 (43)	CueAtyp
71	ALCOHOL	酒		92.44	tequila (69)	龙舌兰 (12)	NoCueTyp
72	ALCOHOL	酒		82.91	champagne (65)	香槟 (67)	NoCueAtyp
73	CLOTHING	衣		94.17	sweater (91)	毛衣 (93)	CueTyp
74	CLOTHING	衣		74.94	raincoat (67)	雨衣 (60)	CueAtyp
75	CLOTHING	衣		97.64	t-shirt (67)	T 恤 (71)	NoCueTyp
76	CLOTHING	衣		70.29	tuxedo (58)	燕尾服 (41)	NoCueAtyp
77	CLOTHING	衣		81.76	coat (72)	大衣 (73)	CueTyp
78	CLOTHING	衣		77.41	pajamas (78)	睡衣 (67)	CueAtyp
79	CLOTHING	衣		97.52	shirt (95)	衬衫 (67)	NoCueTyp
80	CLOTHING	衣		76.26	vest (95)	马甲/背心 (58/21)	NoCueAtyp

81	ELECTRICAL APPLIANCE	电器		82.94	television (96)	电视 (63)	CueTyp
82	ELECTRICAL APPLIANCE	电器		73.79	fan (100)	电扇 (67)	CueAtyp
83	ELECTRICAL APPLIANCE	电器		90.14	microwave (91)	微波炉 (100)	NoCueTyp
84	ELECTRICAL APPLIANCE	电器		84.73	dryer (51)	烘干机 (52)	NoCueAtyp

Appendix B

List of Critical Stimuli in Experiment 2, Chapter 2.

	Category label	Item	Typicality rating	Item word frequency (CELEX_W)	Condition
1	VEHICLE	car	98.26	278.37	CueTyp
2	VEHICLE	train	58.70	75.30	CueAtyp
3	VEHICLE	bus	85.58	65.90	NoCueTyp
4	VEHICLE	tank	43.23	21.63	NoCueAtyp
5	VEHICLE	van	90.20	57.05	CueTyp
6	VEHICLE	ambulance	69.73	8.13	CueAtyp
7	VEHICLE	motor coach	67.35	N/A	NoCueTyp
8	VEHICLE	tractor	51.29	7.35	NoCueAtyp
9	SHOES	sneakers	96.97	1.87	CueTyp
10	SHOES	slippers	52.94	8.25	CueAtyp
11	SHOES	boots	88.85	32.05	NoCueTyp
12	SHOES	clogs	45.76	1.20	NoCueAtyp
13	FLOWER	daffodil	87.73	0.54	CueTyp
14	FLOWER	chrysanthemum	66.26	N/A	CueAtyp
15	FLOWER	tulip	93.70	0.84	NoCueTyp
16	FLOWER	lavender	61.47	2.77	NoCueAtyp
17	FLOWER	orchid	85.23	2.56	CueTyp
18	FLOWER	lotus	70.11	2.05	CueAtyp
19	FLOWER	daisy	91.32	31.99	NoCueTyp
20	FLOWER	dandelion	51.76	1.99	NoCueAtyp
21	TREE	maple	92.64	3.25	CueTyp
22	TREE	poplar	53.23	1.99	CueAtyp
23	TREE	spruce	88.14	2.41	NoCueTyp

24	TREE	bamboo	56.02	6.33	NoCueAtyp
25	TREE	oak	92.11	14.82	CueTyp
26	TREE	willow	82.67	3.92	CueAtyp
27	TREE	birch	86.05	3.92	NoCueTyp
28	TREE	beech	58.14	11.08	NoCueAtyp
29	SEA ANIMAL	dolphin	93.41	1.45	CueTyp
30	SEA ANIMAL	urchin	60.73	1.39	CueAtyp
31	SEA ANIMAL	whale	94.70	6.75	NoCueTyp
32	SEA ANIMAL	clam	60.55	1.57	NoCueAtyp
33	SEA ANIMAL	turtle	84.23	2.35	CueTyp
34	SEA ANIMAL	conch	40.50	11.14	CueAtyp
35	SEA ANIMAL	shark	93.85	14.76	NoCueTyp
36	SEA ANIMAL	scallop	59.88	1.02	NoCueAtyp
37	SEA ANIMAL	starfish	83.50	0.96	CueTyp
38	SEA ANIMAL	manatee	66.00	N/A	CueAtyp
39	SEA ANIMAL	octopus	85.41	1.57	NoCueTyp
40	SEA ANIMAL	oyster	66.47	3.49	NoCueAtyp
41	BIRD	robin	90.41	11.87	CueTyp
42	BIRD	ostrich	64.50	1.75	CueAtyp
43	BIRD	pigeon	93.52	4.04	NoCueTyp
44	BIRD	penguin	54.26	3.61	NoCueAtyp
45	BIRD	woodpecker	83.02	0.60	CueTyp
46	BIRD	flamingo	68.73	0.54	CueAtyp
47	BIRD	crow	91.00	4.22	NoCueTyp
48	BIRD	peacock	68.61	3.01	NoCueAtyp
49	GEM	ruby	94.38	2.59	CueTyp
50	GEM	jade	75.02	1.81	CueAtyp

51	GEM	emerald	89.82	2.29	NoCueTyp
52	GEM	pearl	72.52	8.19	NoCueAtyp
53	GEM	diamond	91.32	8.31	CueTyp
54	GEM	opal	73.85	0.78	CueAtyp
55	GEM	crystal	82.52	12.53	NoCueTyp
56	GEM	quartz	67.08	0.96	NoCueAtyp
57	VEGETABLE	lettuce	93.79	6.87	CueTyp
58	VEGETABLE	parsley	55.55	7.11	CueAtyp
59	VEGETABLE	carrot	95.79	2.65	NoCueTyp
60	VEGETABLE	bean	63.64	4.04	NoCueAtyp
61	VEGETABLE	celery	87.73	2.89	CueTyp
62	VEGETABLE	bok choy	60.38	N/A	CueAtyp
63	VEGETABLE	cucumber	92.26	3.25	NoCueTyp
64	VEGETABLE	eggplant	66.02	N/A	NoCueAtyp
65	VEGETABLE	spinach	85.58	4.46	CueTyp
66	VEGETABLE	beet	68.76	2.41	CueAtyp
67	VEGETABLE	peas	83.50	8.73	NoCueTyp
68	VEGETABLE	potato	75.38	12.29	NoCueAtyp
69	STRING INSTRUMENT	violin	94.14	4.04	CueTyp
70	STRING INSTRUMENT	viola	75.67	0.90	CueAtyp
71	STRING INSTRUMENT	guitar	94.47	5.60	NoCueTyp
72	STRING INSTRUMENT	mandolin	55.76	N/A	NoCueAtyp
73	STRING INSTRUMENT	harp	85.00	2.53	CueTyp

74	STRING INSTRUMENT	cello	84.88	1.93	CueAtyp
75	STRING INSTRUMENT	bass	85.05	9.16	NoCueTyp
76	STRING INSTRUMENT	ukulele	80.38	N/A	NoCueAtyp
77	FRUIT	apple	98.64	18.67	CueTyp
78	FRUIT	fig	54.20	5.78	CueAtyp
79	FRUIT	orange	97.17	31.27	NoCueTyp
80	FRUIT	coconut	50.97	2.41	NoCueAtyp
81	FRUIT	mango	86.79	0.90	CueTyp
82	FRUIT	avocado	45.61	1.39	CueAtyp
83	FRUIT	banana	95.50	4.34	NoCueTyp
84	FRUIT	apricot	62.76	1.57	NoCueAtyp
85	ALCOHOL	beer	94.67	48.55	CueTyp
86	ALCOHOL	cocktail	79.35	8.80	CueAtyp
87	ALCOHOL	vodka	96.67	4.82	NoCueTyp
88	ALCOHOL	brandy	73.70	17.47	NoCueAtyp
89	ALCOHOL	wine	93.29	76.51	CueTyp
90	ALCOHOL	gin	82.23	16.27	CueAtyp
91	ALCOHOL	tequila	92.44	N/A	NoCueTyp
92	ALCOHOL	champagne	82.91	16.75	NoCueAtyp
93	CLOTHING	sweater	94.17	11.69	CueTyp
94	CLOTHING	raincoat	74.94	5.60	CueAtyp
95	CLOTHING	t-shirt	97.64	N/A	NoCueTyp
96	CLOTHING	tuxedo	70.29	0.54	NoCueAtyp
97	CLOTHING	coat	81.76	55.42	CueTyp
98	CLOTHING	pajamas	77.41	N/A	CueAtyp

99	CLOTHING	shirt	97.52	48.13	NoCueTyp
100	CLOTHING	vest	76.26	5.18	NoCueAtyp
101	ELECTRICAL APPLIANCE	television	82.94	105.30	CueTyp
102	ELECTRICAL APPLIANCE	rice cooker	69.14	N/A	CueAtyp
103	ELECTRICAL APPLIANCE	microwave	90.14	2.17	NoCueTyp
104	ELECTRICAL APPLIANCE	kettle	78.38	11.75	NoCueAtyp
105	ELECTRICAL APPLIANCE	refrigerator	90.97	N/A	CueTyp
106	ELECTRICAL APPLIANCE	fan	73.79	11.63	CueAtyp
107	ELECTRICAL APPLIANCE	toaster	87.97	0.66	NoCueTyp
108	ELECTRICAL APPLIANCE	dryer	84.73	1.08	NoCueAtyp

Appendix C

Ethical Approval for the Studies in Chapter 2 and Chapter 3.

Western Research

Research Ethics

Western University Non-Medical Research Ethics Board
NMREB Delegated Initial Approval Notice

Principal Investigator: Prof. Debra Jared
Department & Institution: Social Science\Psychology,Western University

NMREB File Number: 108816
Study Title: Language effects on categorization and perception
Sponsor: Natural Sciences and Engineering Research Council

NMREB Initial Approval Date: January 13, 2017
NMREB Expiry Date: January 13, 2018

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Western University Protocol	Received December 5, 2016	
Recruitment Items	Study 1 - SONA Recruitment	2016/12/05
Letter of Information & Consent	Study 1 - LOI	2016/12/05
Recruitment Items	Study 2 - SONA Recruitment	2016/12/05
Letter of Information & Consent	Study 2 - Bilinguals - LOI	2016/12/05
Letter of Information & Consent	Study 2- Monolinguals - LOI	2016/12/05
Instruments	Language Questionnaire - Monolinguals (Study 1 & 2)	2016/12/05
Instruments	Language Questionnaire - Bilinguals (Study 2)	2016/12/05
Other	Study 1 - Debriefing	2016/12/05
Other	Study 2 - Debriefing	2016/12/05

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the above named study, as of the NMREB Initial Approval Date noted above.

NMREB approval for this study remains valid until the NMREB Expiry Date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario.

Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB [redacted]

[redacted] hair or delegated board member

Ethics Officer: Erika Basile ___ Nicole Kaniki ___ Grace Kelly ___ Katelyn Harris✓___ Vikki Tran ___ Karen Gopaul ___

[redacted]

Appendix D

Language Questionnaire used for English monolinguals in Chapter 2 and Chapter 3

Language History and Experience Questionnaire

Participant #: _______________________

Age:_________ Gender: M F Handedness: Right Left

(1) What is your country of birth? ______________________________

If not Canada, how many years have you lived in Canada? ___________
If you have lived in elsewhere, where did you live and how many years did you live there? ______________________________

(2) List the languages you know:
a) in the order in which you learned them: ___________________________________
b) from the one you know best to the one you know least: _______________________

Language spoken most frequently at home with your family: _______________________
Language spoken most frequently with friends and roommates: ____________________

(3) What percentage of time are you *currently* exposed to each of the following languages in your daily activities (total = 100%)?

English _________
Other _________

(4) Parents' languages

Father's Native Language:___________________ Father's Other Languages: ____________________
Mother's Native Language:__________________ Mother's Other Languages: ____________________

Experience with English

For each of the following English language skills, please indicate the age at which you first started to acquire the skill, the place in which you learned the skill (e.g. home, school), and rate the fluency with which you can currently perform the skill. (Circle one number per skill).

	starting age	place	fluency none									very fluent
Understanding			1	2	3	4	5	6	7	8	9	10
Speaking			1	2	3	4	5	6	7	8	9	10
Reading			1	2	3	4	5	6	7	8	9	10
Writing			1	2	3	4	5	6	7	8	9	10

Version date: December 5, 2016

Appendix E

Language Questionnaire used for bilinguals in Chapter 2 and Chapter 3.

Language History and Experience Questionnaire

Participant #: _______________________

Age:_________ Gender: M F Handedness: Right Left

(1) What is your country of birth? ______________________________
How many years have you lived in Canada? ___________
If you have lived in China, how many years did you live there? __________

(2) List the languages you know:
a) in the order in which you learned them: ___________________________________
b) from the one you know best to the one you know least: _______________________

Language spoken most frequently at home with your family: _______________________
Language spoken most frequently with friends and roommates: ____________________

(3) What percentage of time are you *currently* exposed to each of the following languages in your daily activities (total = 100%)?

Mandarin Chinese _________
English _________
Other _________

(4) Do you speak any Chinese dialects *other* than standard Mandarin Chinese? Please check any that apply:

☐ Cantonese ☐ Taiwanese ☐ Other (please specify) _______________

(5) Parents' languages

Father's Native Language:___________________ Father's Other Languages: ____________________

Mother's Native Language:__________________ Mother's Other Languages: ____________________

Experience with English

For each of the following English language skills, please indicate the age at which you first started to acquire the skill, the place in which you learned the skill (e.g. home, school), and rate the fluency with which you can currently perform the skill. (Circle one number per skill).

	starting age	place	fluency none									very fluent
Understanding			1	2	3	4	5	6	7	8	9	10
Speaking			1	2	3	4	5	6	7	8	9	10
Reading			1	2	3	4	5	6	7	8	9	10
Writing			1	2	3	4	5	6	7	8	9	10

Experience with Mandarin

For each of the following Mandarin language skills, please indicate the age at which you first started to acquire the skill, the place in which you learned the skill (e.g. home, school), and rate the fluency with which you can currently perform the skill. (Circle one number per skill).

	starting age	place	fluency none									very fluent
Understanding			1	2	3	4	5	6	7	8	9	10
Speaking			1	2	3	4	5	6	7	8	9	10
Reading			1	2	3	4	5	6	7	8	9	10
Writing			1	2	3	4	5	6	7	8	9	10

School Experience

Indicate the type of schooling that you received at each grade level by placing an 'x' in the appropriate box.

	K1	K2	1	2	3	4	5	6	7	8	9	10	11	12	U1	U2	U3	U4
Mandarin school (no English course)																		
Mandarin school (an English course)																		
English school (no Mandarin course)																		
English school (a Mandarin course)																		

Version date: December 5, 2016

Curriculum Vitae

Name: Xuan Pan

EDUCATION

2014-2019: PhD Psychology, Cognitive, Developmental and Brain Sciences
University of Western Ontario, London, Ontario, Canada.
Advisor: Dr. Debra Jared.

2011-2014: MEd Psychology, Physiological and Cognitive Psychology
Nanjing Normal University, Nanjing, Jiangsu, China.
Advisor: Dr. Chang Liu.

2006-2010: BSc Psychology, Applied Psychology
China University of Political Science and Law, Beijing, China.
Advisor: Dr. Bo Yang

PEER-REVIEWED PUBLICATIONS

Pan, X., & Yu, H. (2018). Different effects of cognitive shifting and intelligence on creativity. *Journal of Creative Behavior*, 52(3), 212-225. doi: 10.1002/jocb.144.

Pan, X. (2013). Boredom Syndrome and juvenile delinquency. *Criminal Research, 4,* 53-58. (in Chinese, **潘旋** (2013). 无聊症候群与青少年犯罪. *犯罪研究, 4,* 53-58.)

PUBLICATIONS UNDER REVIEW

Pan, X., & Jared, D. Effects of Chinese word structure on object perception in Chinese-English bilinguals: A test of the label feedback hypothesis using a visual oddball paradigm.

CONFERNCE PRESENTATIONS

Pan, X., & Jared, D. (2018, November). The effects of linguistic labels on object categorization and perception. The Psychonomics Society 2018 Annual Meeting, New Orleans, USA.

Chi, Z., **Pan, X.**, & Lupker, S. (2018, November). A further examination of transposed radical priming effects in Chinese character recognition. The Psychonomics Society 2018 Annual Meeting, New Orleans, USA.

Pan, X., & Jared, D. (2018, September). The effects of language on categorization and perception. 11th International Conference on The Mental Lexicon, Edmonton, Canada.

Pan, X., & Lupker, S. (2017, November). Transposed radical priming effects in Chinese. The Psychonomics Society 2017 Annual Meeting, Vancouver, Canada.

Pan, X., & Jared, D. (2016, November). Conceptual representation in Mandarin-English bilinguals: An ERP study. The Psychonomics Society 2016 Annual Meeting, Boston, USA.

Jared, D., Xiong, A., **Pan, X.**, & Jouravlev, O. (2015, November). Lexical conceptual representations in bicultural bilinguals. The Psychonomics Society 2015 Annual Meeting, Chicago, USA.

Pan, X. (2015, June). The relationship between creativity and cognitive switching: Mediating effect of intelligence. Canadian Society for Brain, Behaviour and Cognitive Science, Ottawa, Canada.

PROFESSIONAL EXPERIENCE

2018: Course Instructor for Bilingualism (Fall), Department of Psychology, University of Western Ontario.

2016-2018: Teaching Assistant for Psychology Honors Thesis, Department of Psychology, University of Western Ontario.

2015-2016: Teaching Assistant for Research in the Psychology of Language (Fall), and Introduction to Psychology (Winter)

2014-2015: Teaching Assistant for Research in the Psychology of Language (Fall), Psychology of Language (Winter), and Child Development (Winter)

2013: Coordinator, Investigation of key psychological characteristics of Chinese, Institute of Psychology, Chinese Academy Sciences.

2009: Assistant Consultant, Mental Health and Counseling Center, China University of Political Science and Law, Beijing, China.

WORKSHOPS ATTENDED

2018: Mitacs Training workshop: Skills of Communication, University of Western Ontario, London, Canada. January 2018.

2017: Analysing Interactions and Non-Linear Effects in Mixed-Effect Models, McMaster University, Hamilton, Canada. November 2017.

2016: EEG/ERP Summer Workshop at BMI, University of Western Ontario, London, Canada. May 2016.

2015: Teaching in the Canadian Classroom, Teaching Support Centre, University of Western Ontario, April 2015.

2015: The Language of Difficult Conversations, Teaching Support Centre, University of Western Ontario, August 2015.

2015: Communication in the Canadian Classroom, Teaching Support Centre, University of Western Ontario, October 2015.

2012: Confirmatory Factor Analyses and Structural Equation Modeling, Nanjing University, Nanjing, China. December 2012.

HONOURS AWARDED

2014-2018: Western Graduate Research Scholarship

2014: Outstanding Graduates, Nanjing Normal University

2013: Outstanding Graduate Student, Nanjing Normal University

2011-2014: Graduate Research Scholarship, Nanjing Normal University

2010: Outstanding Intern, China University of Political Science and Law

2007: University Scholarship, China University of Political Science and Law