BILINGUALISM IN INFANCY: A WINDOW ON LANGUAGE ACQUISITION

by

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Abstract

To rise to the challenge of acquiring their native language, infants must deploy tools to support their learning. This thesis compared infants growing up in two very different language environments, monolingual and bilingual, to better understand these tools and how their development and use changes with the context of language acquisition.

The first set of studies – Chapter 2 – showed that infants adapt very early-developing tools to the context of their prenatal experience. Newborns born to bilingual mothers directed their attention to both of their native languages, while monolinguals preferred listening to their single native language. However, prenatal bilingual experience did not result in language confusion, as language discrimination was robustly maintained in both monolinguals and bilinguals. Thus, learning mechanisms allow experience-based listening preferences, while enduring perceptual sensitivities support language discrimination even in challenging language environments.

Chapter 3 investigated a fundamental word learning tool: the ability to associate word and object. Monolinguals and bilinguals showed an identical developmental trajectory, suggesting that, unlike some aspects of word learning, this associative ability is equivalent across different types of early language environments.

Chapters 4 and 5 explored the development of a heuristic for learning novel words. Disambiguation is the strategy of associating a novel word with a novel object, rather than a familiar one. In Chapter 4, disambiguation was robustly demonstrated by 18-month-old monolinguals, but not by age-matched bilinguals and trilinguals. The results supported the “lexicon structure hypothesis”, that disambiguation develops with mounting evidence for a one-to-one mapping between words and their referents, as is typical for monolinguals. For bilinguals, translation equivalents (cross-language synonyms) represent a departure from
one-to-one mapping. Chapter 5 directly tested the lexicon structure hypothesis, by comparing subgroups of bilinguals who knew few translation equivalents to bilinguals who knew many. Only the former group showed disambiguation, supporting the lexicon structure hypothesis.

The series of studies presented in this thesis provides a window into language acquisition across all infants. Whether growing up monolingual or bilingual, infants harmonize their development and use of the tools of language acquisition to the particular challenges mounted by their language environment.
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Co-authorship statement

The ideas presented in this thesis are those of the author, developed through discussion and collaboration with supervisor Dr. Janet F. Werker. This body of research was conducted with the invaluable assistance of several colleagues, whose contribution is reflected in the author line of each of the papers either already published or in the process of publication, which have arisen from this work. The reference for each paper is provided as a footnote on the first page of the relevant chapter. For the research reported in Chapter 2, Study 1 was initially developed by Janet F. Werker, and data collection was initially coordinated by Tracey C. Burns. Study 2 was developed by the author, and the author had primary responsibility for all aspects of Study 2, including design, data collection and analysis, and interpretation of the results. The author subsequently completed further data collection and all analysis of Study 1, and wrote the manuscript that included both Study 1 and Study 2. Tracey C. Burns and Janet F. Werker contributed to improving and editing the manuscript. For chapters 3, 4, and 5, hypothesis generation, study design, data collection, data analysis, and interpretation of results, and manuscript preparation were completed primarily by the author in collaboration with and under the supervision of Janet F. Werker. Co-author Christopher T. Fennell contributed to the improving and editing of Chapter 3. The monolingual and bilingual groups reported in Study 1 of Chapter 4 formed a thesis for the degree of Master of Arts, awarded in 2006 to the author. These are included here for the coherence of this document, and to provide a context for the additional data included in this Chapter 4.
1 Introduction

1.1 General overview

Language is a hallmark of the human species, and is passed unfalteringly from adults to infants across generations. There are over 6900 different living languages (Lewis, 2009) which, while sharing fundamental structural similarities, vary in the surface form by which ideas are communicated. As a consequence, human infants cannot be born with the knowledge of any particular language, but rather must learn the specifics of their native language over the first few years of life. To this end, it is necessary for infants to be equipped with a common set of tools for perception and learning, which together with possible innate knowledge or predispositions, have the flexibility and power to enable the acquisition of any of the world’s languages.

How far does this preparedness and flexibility for language learning extend? In Canada, individuals from more than half a million households report speaking more than one language regularly (Statistics Canada, 2006). Thus, many babies grow up hearing two languages rather than one. The infant capacity for language acquisition seems to extend even to learning two languages simultaneously from birth. Beginning from the first empirical examination of infant bilingualism nearly 100 years ago (Ronjat, 1913), research has suggested that infants can successfully acquire two languages simultaneously (De Houwer, 1990; Deuchar & Quay, 1999; Yip & Matthews, 2007). The nature of bilinguals’ early productions indicates success across both languages in terms of conceptual, vocabulary, and grammatical development (Genesee & Nicoladis, 2007; Holowka, Brousseau-Lapre, & Petitto, 2002; Meisel, 2001; Pearson, Fernández, & Oller, 1993; Pearson & Fernández, 1994; Pearson, Fernández, & Oller, 1995; Pearson, Fernández, Lewedeg, & Oller, 1997; Pearson, 1998; Petitto et al., 2001).
Although the broad strokes of monolingual and bilingual development are highly similar, there are important differences between the challenges faced by infants growing up monolingual and those faced by infants growing up bilingual. As François Grosjean (1989) aptly observed, “The bilingual is not two monolinguals in one person.” Bilingual infants must juggle two systems for communicating about the world: they must learn two sets of sounds, two words to name every concept, and two grammars with which to order these words into meaningful sentences. While they encounter these two languages, they must constantly discriminate and separate the languages in the input, in order to learn each language in and of itself, rather than an amalgam of the two. Bilinguals also face challenges in how their languages interact with other cognitive systems. For example, evidence from adults suggests that the bilingual’s two language systems interface with a single shared conceptual system (Ameel, Storms, Malt, & Sloman, 2005), which adds to the complexity of linking up words and concepts in vocabulary acquisition.

Elsewhere, in collaboration with Werker, I have put forward the idea that “the human mind is as prepared to acquire two first languages as it is to acquire one,” (Werker & Byers-Heinlein, 2008, p.144). However, we have also argued that, “the same proclivities and learning mechanisms that support language acquisition unfold somewhat differently in bilingual versus monolingual environments,” (Werker, Byers-Heinlein, & Fennell, 2009, p. 3649). This thesis presents an empirical examination of these propositions, by testing how the tools that support language acquisition develop and are used in bilingual as opposed to monolingual environments. A comparison of how monolinguals and bilinguals develop and use tools of acquisition given their different early language environments can illuminate the nature and origins of the tools themselves.

This thesis focuses on infants’ achievements in language acquisition in the first two years of life including 1) the tuning of the perceptual system to the characteristics of the
native language, and 2) the onset of word learning. Early accomplishments in these domains set the stage for language acquisition throughout childhood. This thesis investigates the tools that propel speech perception and word learning during the first two years of life, exploring how these develop similarly or differently across monolingual and bilingual environments, and the consequent implications for theories of language acquisition.

1.2 Tools for speech perception

Whether in the context of a monolingual or of a bilingual environment, language acquisition is rooted in infants’ perception of speech. Newborn infants prefer speech sounds over non-speech (Vouloumanos, Hauser, Werker, & Martin, 2010; Vouloumanos & Werker, 2007) and already demonstrate important linguistic capacities such as the categorical perception of consonant sounds (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). The tuning of these early predispositions begins as infants listen to their native language, setting the stage for subsequent linguistic achievements (Curtin & Werker, 2007; Saffran, Werker, & Werner, 2006; Werker & Yeung, 2005). Even before they speak their first words, studies have demonstrated that monolingual infants are already aware of numerous properties of the native language, including its rhythm, speech sound categories, and phonotactic characteristics. The following sections will review the early achievements of infants growing up bilingual in each of these domains, to illuminate early links between bilingual experience and the tools used for speech perception.

1.2.1 Tuning to the native languages.

In order to learn two languages simultaneously, bilingual infants must be able to discriminate amongst different languages, and eventually separate these in the input stream. Early perceptual sensitivity to the rhythmical characteristics of different languages could provide a foothold into language separation for bilingual infants. Studies with infants
born to monolingual French-speaking mothers suggest that these infants possess perceptually-based tools to discriminate a variety of language pairs from birth, although not all language pairs are discriminated (Mehler et al., 1988; Nazzi, Bertoncini, & Mehler, 1998; Ramus, Hauser, Miller, Morris, & Mehler, 2000). Successful discrimination of two languages appears to relate to the languages’ rhythmicities: at birth, infants can discriminate languages that are from two different rhythmic classes (e.g. stress-timed English from syllable-timed French) but not languages that are from the same rhythmic class (e.g. English and German, both stress-timed; see Ramus, Nespor, & Mehler, 1999, for an acoustic typology of rhythmic classes). Even at 2 months-of-age, languages from the same rhythmic class may not be discriminated (Christophe & Morton, 1998).

It is only several months after birth that infants have developed the tools to achieve within-rhythmic class distinctions, and here both monolingual and bilingual infants have been studied. By age 5 months, monolinguals can discriminate language pairs from within the rhythmic class of the native language, but not pairs from other rhythmic classes, suggesting increased sensitivity to the properties of the native language (Nazzi, Jusczyk, & Johnson, 2000). Importantly, bilingual infants exposed to rhythmically-similar languages from birth show discrimination of these languages as early as 4 months, as demonstrated by studies of the discrimination of Spanish and Catalan (both syllable-timed languages) by bilingual infants exposed to these two languages (Bosch & Sebastián-Gallés, 1997; Bosch & Sebastián-Gallés, 2001). Early abilities to discriminate rhythmically distinct languages, and later-developing abilities to make fine-grained distinctions between rhythmically similar languages that are native, imply that bilingual infants have the tools available to discriminate any language pair they might encounter.

Auditory language discrimination is not the only tool available to infants in differentiating between different languages. Infants are also sensitive to visual correlates
that distinguish different languages (Weikum et al., 2007). When the stimuli consist of silent talking faces speaking either English or French, at 4- and 6-months-of-age, both monolingual English-learning and French-English bilingual infants can discriminate the two languages. However, at 8-months-of-age only bilinguals show successful discrimination, while monolinguals fail. This pattern of results is thought to be because of bilinguals’ ongoing exposure to faces speaking each language, which likely maintains the tools necessary for visual language discrimination.

Experience early in life not only tunes infants’ discrimination abilities, but also alters their perception of native versus unfamiliar languages. Studies with 4-month-old Catalan-monolingual, Spanish monolingual, and Spanish-Catalan bilingual infants have shown that infants respond differently to their native language(s) as compared to an unfamiliar language (Bosch & Sebastián-Gallés, 1997). Surprisingly, the effect of native language listening has been shown to extend to the newborn period. Moon and colleagues (Moon, Cooper, & Fifer, 1993) compared the language preference (English versus Spanish) in newborn infants born either to monolingual English-speaking mothers or to monolingual Spanish-speaking mothers. Both groups of newborns preferred their native language over the unfamiliar one. These results indicate that, at least in the case of monolingual infants, prenatal language experience influences speech perception at birth, and serves to direct infants’ attention to the native language.

To summarize, by at least age 4 months, bilingual infants have access to tools that enable the recognition of their native languages, and the discrimination of different language pairs both in the auditory and visual domains. Evidence from monolingual infants suggests that prenatal experience with the native language can influence perception at birth, but no studies to date have looked at speech perception in newborns with prenatal bilingual experience. Chapter 2 of this thesis will thus examine language discrimination and
language preference at birth in bilingual newborns. Familiarity with both languages, together with access to tools for language discrimination might be an important precursor to subsequent bilingual development, allowing bilingual babies to eventually build two language systems.

1.2.2 Phonetic development.

One way that languages differ from one another is in how they categorize speech sounds (e.g. English makes a difference between the /l/ and /r/ sounds, but Japanese does not). Before they begin learning words, infants must come to know what speech sound variation falls within the same category, and when variation marks a difference between two categories. Early in their first year, monolingual infants discriminate most speech sound contrasts present in the world’s languages, and their perception becomes tuned over the next several months to maintain just those distinctions that are phonemic (signify a change in meaning) in the native language (Werker & Tees, 1984). Evidence from monolingual infants suggests that tools for tracking the distribution of speech sounds (Maye, Weiss, & Aslin, 2008; Maye, Werker, & Gerken, 2002; Vallabha, McClelland, Pons, Werker, & Amano, 2007; Werker et al., 2007), and the patterns of co-occurrence between sounds and objects (Yeung & Werker, 2009) support the modification of speech sound categories.

Compared to monolinguals, bilinguals face a more complicated landscape of speech sounds (for a recent review, see Curtin, Werker, & Byers-Heinlein, under review). Depending on the language pairs they are learning, some speech sound contrasts are phonemic in one language, but not in the other. Further, certain speech sound categories can be realized differently across the two languages. Bilingual infants face the challenging task of maintaining speech sound differences that are meaningful within each of their languages, and possibly those that mark differences across the two languages. Although
studies have not yet directly examined whether bilinguals have access to the same tools as monolinguals for phonetic learning, there are numerous studies showing similar timing in the establishment of native speech sound categories, especially for consonants (Burns, Yoshida, Hill, & Werker, 2007; Sundara, Polka, & Molnar, 2008). Generally, bilinguals also establish native vowels categories by the end of the first year of life (Albareda-Castellot, Pons, & Sebastián-Gallés, under review; Bosch & Sebastián-Gallés, 2003; Sebastián-Gallés & Bosch, 2009), although certain studies suggest that some close vowel contrasts might be temporarily collapsed at age 8-months (Bosch & Sebastián-Gallés, 2003; Sebastián-Gallés & Bosch, 2009). The effects of bilingual experience on phonetic development is thus roughly parallel to the effects of monolingual experience, serving to tune the system to differences that will be meaningful as the infant begins to learn new words.

### 1.2.3 Phonotactic development.

Related to the development of speech sound categories is infants’ knowledge of the order in which these speech sounds can appear in a word, or the phonotactics of a language. Phonotactic knowledge is an important precursor to word learning. Monolingual infants show a preference for phonotactically legal sequences over illegal ones (Jusczyk, Luce, & Charles-Luce, 1994). Such knowledge of phonotactic regularities can help infants segment words from the speech stream (Mattys, Jusczyk, Luce, & Morgan, 1999; Mattys & Jusczyk, 2001).

Only one study to date has investigated phonotactic development in bilingual infants. In a study with 10-month-olds, monolingual Spanish and monolingual Catalan-learning infants showed greater interest in sound sequences that were phonotactically legal over those that were phonotactically illegal in the native language (Sebastián-Gallés & Bosch, 2002). However, when Catalan-Spanish bilinguals were tested on Catalan sequences, only those infants who were dominant in Catalan showed a preference for the legal
sequences over the illegal ones, while Spanish-dominant infants did not show this preference. Adult bilingual participants showed similar effects of dominance. These results suggest that the tools supporting phonotactic learning may require a threshold of sufficient input, which may not be met in the bilingual’s non-dominant language. Less robust phonotactic knowledge in the non-dominant language could make it more difficult for bilinguals to extract words from the speech stream.

1.3 Tools for word learning

Word learning is a multi-faceted process that builds on the perceptual sensitivities discussed above. Infants must have tools that enable them to segment words from the speech stream, encode sufficient phonetic detail of the word, and eventually link this word form to its referent, even in referentially ambiguous contexts. Further, throughout word learning, bilingual infants juggle speech sound categories from two languages, and words that come from different languages. Next, I will review the literature to date that speaks to bilinguals’ early successes and challenges at these tasks.

1.3.1 Word form recognition.

Even before infants begin to associate words with their referents, they start to pick out common word forms that occur in the speech stream (Jusczyk, 1997, 1999). Infants are thought to use a variety of tools for this purpose. Some are likely useful in any language learning context, such as detecting statistical patterns of co-occurrence between syllables that identify statistically coherent words (Aslin, Saffran, & Newport, 1998; Saffran, Aslin, & Newport, 1996). Other tools are specific to a particular language, such as lexical stress cues that mark the onset of many words in English (Cutler & Norris, 1988; Thiessen & Saffran, 2003). Several studies with adults have indicated that language-specific segmentation tools are only available in the bilinguals’ dominant language, and not in their non-dominant
language. (Cutler, Mehler, Norris, & Segui, 1989; Dupoux, Peperkamp, & Sebastián-Gallés, 2010). These results, together with the finding of less robust phonotactic knowledge in bilinguals’ non-dominant language (Sebastián-Gallés & Bosch, 2002), suggest that bilingual infants might have difficulty segmenting words from their non-dominant language, making word form learning difficult.

There is some evidence that bilingual infants show different responses to word forms in their dominant as compared to in their non-dominant language. In a study of 19-22 month-old Spanish-English bilinguals, researchers compared infants’ brain responses (using event-related potentials) to words that were either known or unknown (Conboy & Mills, 2006). Brain responses to known words in the dominant language showed a left-lateralized response that was highly similar to that of same-aged monolingual infants. However, responses to known words in the non-dominant language were later in latency, and less lateralized. These results suggest an important difference between the dominant and non-dominant language, which could either originate in differences in initial segmentation of word forms, in subsequent encoding of the segmented words, or both.

However, a study of younger bilingual infants did not report any effects of dominance. Vihman and colleagues (Vihman, Thierry, Lum, Keren-Portnoy, & Martin, 2007) tested word form recognition in bilingual English-Welsh learning toddlers using both behavioral and electrophysiological measures. At age 11-months, infants showed behavioral evidence of preferring to listen to words that are frequent in the input over infrequent words. Similarly, in an event-related potential version of the study, bilingual infants again showed a brain signature characteristic of recognition of these frequent word forms, and did so in each of their languages. It may be that the effects of dominance are not yet strong enough to be detected at this young age.
1.3.2 **Associative word learning.**

Once infants have extracted a candidate word form, a next step in word learning is to link this word with its referent. An important distinction is to be made between word learning as a simple association between a word and a particular referent, and word learning as full referential understanding of that word. Associative word learning entails a simple “goes with” relationship between word and object. When a noun is known in an associative fashion, its meaning is specific to a particular instance of an object or its perceptual properties, and generalizations of the words’ meaning are not made to other objects of the same category. Referential word learning entails a deeper understanding of a word as a symbol for an object category. Words that have been learned in the referential sense can be extended to new instances of the same category, and can be shown to evoke the referent even when it is not present (Bloom & Markson, 1998; Preissler & Carey, 2004).

Some have argued that word learning changes in quality over the second year of life, transitioning from being characterized by associative word learning to later being referential (Nazzi & Bertoncini, 2003), while others have argued that word learning even in early infancy entails reference, rather than mere associations (Waxman & Gelman, 2009).

Infants’ ability to associate a word and an object under highly controlled conditions has often been measured via the “Switch” task (Werker, Cohen, Lloyd, Casasola, & Stager, 1998; for earlier foundations of this method see Younger & Cohen, 1986). Success in the Switch task requires at minimum an ability to form an associative link between a word and a particular object, although success would also be seen if infants form a more sophisticated referential link between the word and the category that the object instantiates. In the Switch task, infants repeatedly see two word-object pairings. Across semi-randomized trials, object A is shown moving across a television screen accompanied by word A, and object B is similarly shown accompanied by word B. Presentation continues until
habituation is reached, whereby the infant shows declined interest in these stimuli as measured by the infant’s looking time towards the screen. At test, the infant sees two types of trials. On the Same trial, the infant sees a pairing that was shown during habituation, e.g. object A-word A. The Same trial is expected to be relatively uninteresting, as this has been seen repeatedly during habituation. On the Switch trial, the infant sees a novel pairing: a mismatched combination that was never seen before, e.g. object A-word B. In this case, both the object itself and the word itself are familiar. However, what is novel is the pairing between the two. Thus, if infants have successfully associated the word and the object, they will be surprised by this novel pairing and will show increased visual interest towards the screen.

Studies of monolinguals have revealed that infants can succeed at the Switch task by age 14 months when the two words are dissimilar-sounding, like *lif* and *neem* (see Curtin, 2009 for evidence of success in the Switch task at 12 months). Surprisingly, when the words are minimally different such as *bih* and *dih*, monolingual infants only succeed at 17-months-of-age (Stager & Werker, 1997; although see Thiessen, 2007; Werker et al., 1998; Werker, Fennell, Corcoran, & Stager, 2002; Yoshida, Fennell, Swingley, & Werker, 2009 for conditions under which monolinguals do succeed at 14-months).

How do bilingual infants fare in the Switch task, and is their performance similar to that of monolinguals on both the minimal-pair version and the more basic version that tests the learning of dissimilar-sounding words? Intertwining sensitivities to sounds, objects, and their co-occurrence are foundational as infants begin learning new words and building their vocabularies (Yeung & Werker, 2009). However, bilinguals’ more complex phonetic and associative environment could make both minimal-pair and non-minimal pair word learning more challenging for these infants.
The learning of dissimilar-sounding words by bilinguals has been largely neglected in experimental studies of bilingual acquisition, with the only studies to date investigating bilinguals’ ability to learn minimal-pair words. For example, Fennell and colleagues (Fennell, Byers-Heinlein, & Werker, 2007) used the Switch task to investigate infants’ ability to learn minimal pair words *bih* and *dih*. Stimuli were recorded by a native English speaker. While monolinguals successfully associate novel labels *bih* and *dih* with two different objects at 17 months-of-age (Stager & Werker, 1997), bilinguals from three different backgrounds (French-English, Chinese-English, and a heterogeneous group of English-other bilinguals) all failed at this same age. Only at 20 months did bilingual infants show success at minimal pair word learning.

Other studies of minimal pair word learning provide evidence that bilinguals might be highly sensitive to small phonetic cues in the stimuli. Mattock and colleagues (Mattock, Polka, Rvachew, & Krehm, 2010) tested infants’ ability to learn minimal pair words *bos* and *gos*, but varied subtle properties of the stimuli. Infants heard tokens from a native bilingual adult speaker either pronounced in a French manner, an English manner, or in a manner that was intermediate between the English and French pronunciations. At 17 months-of-age, both monolingual and bilingual infants succeeded only in learning minimal pairs that were produced in a manner corresponding to their language environment. Monolingual French-learning infants succeeded on French tokens, but failed on English and bilingual tokens. Monolingual English-learning infants succeeded on English tokens but like French monolinguals failed on the bilingual tokens. However, bilingual French-English infants did succeed on the bilingual tokens. Based on these results, it is possible that bilinguals’ failure at 17-months in Fennell et al.’s study (2007) was because the tokens used were pronounced in an English manner. However, because the two studies used different minimal pair words, it is difficult to fully compare their results before more empirical work is done.
There is a further reason why it is difficult to draw strong conclusions about monolingual and bilingual infants’ different patterns of performance on the minimal pair Switch task. Minimal pair word learning engages at least two tools of language acquisition simultaneously: a perceptual ability that supports infants’ detection and encoding of the fine phonetic detail present in the minimal pair words, and an associative tool that allows them to link these minimal pair words with two different objects. No study to date has pulled these two tools apart in bilingual infants. Monolinguals’ learning of minimal pair words can be contrasted with their earlier success at learning dissimilar-sounding words. However, as mentioned above, bilinguals have not yet been tested in the Switch task on dissimilar-sounding words, thus it is unknown whether part of the difficulty with minimal pairs results from an intertwined difficulty with general associative word learning. Chapter 3 of this thesis will present data on monolingual and bilingual infants at 2 ages (12- and 14-months) to determine whether this fundamental tool for word learning develops on the same schedule in these two groups, by using the Switch task to test the learning of dissimilar-sounding words.

1.3.3 Word learning heuristics.

In the Switch task, infants are provided with reasonably unambiguous cues as to the referent of the novel word; during habituation there is only ever a single object onscreen which is always presented with the same word. However, in real life monolinguals and bilinguals both encounter word-learning situations in which the referent of a particular word is not clear. In Quine’s (1960) famous Gavagai tale, a speaker of a foreign language points to a rabbit scurrying across a field and says “Gavagai!” What should an English-speaking linguist watching this scene take the word gavagai to mean? There are many reasonable hypotheses: it could mean a rabbit, an animal, or the colour white. There are also many hypotheses that somehow seem less reasonable, for example that gavagai refers
to “undetached rabbit parts”. Children do not consider all possibilities equally, but rather show systematic biases and heuristics in their interpretation of novel words (e.g. Golinkoff, Mervis, & Hirsh-Pasek, 1994; Landau, Smith, & Jones, 1988; Markman & Hutchinson, 1988; Markman, 1989; Soja, Carey, & Spelke, 1991).

One word learning heuristic that children use as they narrow down the referent of a novel word is disambiguation (Merriman & Schuster, 1991). As early as 16-17 months-of-age, monolingual infants can disambiguate the meaning of a novel label by assuming it refers to a novel object, rather than to a familiar one (Halberda, 2003; Markman, Wasow, & Hansen, 2003). One explanation for the origin of this heuristic is that children have a default assumption that object labels are mutually exclusive, and thus avoid mapping the second label onto the familiar object (Markman & Wachtel, 1988). However, there are other competing accounts of disambiguation, including socio-pragmatic reasoning (Clark, 1990; Clark, 1992; Diesendruck & Markson, 2001; Diesendruck, 2005), and a direct motivation to map the novel label to the novel object rather than an avoidance of a second label for the familiar object (Mervis & Bertrand, 1994; Momen & Merriman, 2002).

How useful is disambiguation in the bilingual context? If bilinguals operate under an assumption of mutual exclusivity, they might fail to learn two words for the same object even if the words are in different languages. On the other hand, if disambiguation is motivated by a tendency to map novelty to novelty, there is no reason why it should differ across monolinguals and bilinguals. Some investigations of disambiguation have tested whether bilinguals might therefore be less likely to use disambiguation and related behaviors than monolinguals and there has been some support for this prediction in studies of preschoolers and school-aged children (Davidson, Jergovic, Imami, & Theodos, 1997; Diesendruck, 2005; Houston-Price, Caloghiris, & Raviglione, 2010; Merriman & Kutlesic, 1993; but see also Au & Glusman, 1990; Frank & Poulin-Dubois, 2002).
Rather than bilingual experience changing an in-built bias like mutual exclusivity, it may be that early bilingual experience alters whether and how word learning heuristics like disambiguation develop (see Houston-Price et al., 2010, for a recent contribution). Chapters 4 and 5 will thus compare how early use of disambiguation differs in infants from monolingual and bilingual backgrounds. An examination of whether bilingual experience influences the development of disambiguation can illuminate the developmental origins of disambiguation, and what type of experience is necessary for its emergence.

### 1.3.4 Word comprehension.

As described above, infants have word learning tools available to help them figure out the reference of a novel word, and to form an association between a word and its referent. However, once stored in memory, infants must be able to retrieve the meaning of a word. This is the task faced by infants in word recognition.

One published study to date has investigated how bilingual infants recognize the referents of familiar words. Spanish-Catalan bilinguals were tested on how a mispronunciation of familiar a word would affect infants' word recognition (Ramon-Casas, Swingley, Sebastián-Gallés, & Bosch, 2009). Mispronunciations involved a substitution of /e/ for /ɛ/ or vice versa, a change which is meaningful in Spanish but not in Catalan. Bilinguals who were dominant in Catalan behaved like Catalan monolinguals, and were hindered in recognizing words that had been mispronounced. Bilinguals who were dominant in Spanish showed no effect of the mispronunciation, a pattern also shown by Spanish monolinguals. This latter result was surprising, as even for Spanish-dominant bilinguals, the existence of this contrast in one of their languages should have led infants to detect the mispronunciation. On a control task that involved a mispronunciation that was phonemic in both languages, bilinguals did detect the mispronunciation, indicating that the original result was not due to an overall decrease in sensitivity to sound contrasts in word
recognition tasks. Thus, bilingual infants have the tools necessary for the general task of word recognition, but as in the case of minimal pair words, might face challenges in using subtle phonetic information. Chapters 4 and 5 will capitalize on the availability of familiar word recognition tools to both monolingual and bilingual infants, by using familiar word recognition as a control task from which to compare infants’ ability to disambiguate novel words.

1.4 Thesis rationale

Studying infants growing up in bilingual environments provides a fascinating opportunity to examine how the tools of language acquisition develop across different early language contexts. Monolingual and bilingual infants face different types of language learning challenges, yet achieve language milestones on the same schedule. This thesis will investigate tools of language acquisition at 3 different ages in both monolingual and bilingual infants.

Chapter 2 investigates language acquisition tools that might be available from the first days of life, and explores how prenatal experience with two languages affects their use. Two sets of studies investigate 1) language preference in newborn infants as evidence of prenatal learning about the native languages and 2) the bilingual infants’ ability to maintain discrimination of their native languages. Effects of prenatal bilingual experience would push back the clock on the youngest age at which bilingualism has been shown to affect speech perception (previously 4 months; Bosch & Sebastián-Gallés, 1997; Bosch & Sebastián-Gallés, 2001), and will identify perceptual capabilities that are robust across different early language environments.

Chapter 3 moves from the influence of bilingualism on speech perception to the influence of bilingualism on a fundamental tool that supports word learning: the ability to associate words and objects. Monolinguals and bilinguals will be tested at 12- and 14-
months-of-age to establish the developmental trajectory of infants’ associative word learning abilities.

Chapters 4 and 5 ask how bilingualism might affect later-developing tools of word learning, in particular infants’ use of the disambiguation word learning heuristic at age 18-months. Chapter 4 evaluates whether the schedule of emergence of disambiguation is the same across monolingual, bilingual, and trilingual infants. This chapter demonstrates that the specific nature of the language environment can affect the development of word learning tools.

Chapter 5 builds on the findings of Chapter 4, in an attempt to establish what aspect of the multilingual environment changes the development of disambiguation in these infants relative to monolinguals.

Chapter 6 provides a discussion of the findings of the preceding chapters, pointing to the contributions they make to the fields of language acquisition and bilingualism, discussing both strengths and limitations of the research, and suggesting directions of future inquiry.
1.5 References


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2 The roots of bilingualism in newborns

2.1 Introduction

The human affinity for language begins at or before birth. Neonates show many perceptual sensitivities that are important for language acquisition (Gervain & Werker, 2008). In monolingual acquisition, infants must detect and learn the regularities that characterize a single language. In bilingual acquisition, infants must simultaneously detect and learn the regularities of each of two languages. This requires recognizing both languages as native while continuing to discriminate them. What tools do neonates have available to negotiate a bilingual environment?

To break into two languages and bootstrap acquisition, one source of information that bilingual infants might use is rhythmicity (Mehler, Dupoux, Nazzi, & Dehaene-Lambertz, 1996). Traditionally, the world's languages have been classified into three rhythmic classes: stress-timed (e.g., Dutch), syllable-timed (e.g., French), and mora-timed (e.g., Japanese). Ramus, Nespor, and Mehler (1999) identified two acoustic dimensions that correlate with rhythmic-class distinctions: the standard deviation of the duration of consonant intervals within each sentence (ΔC) and the proportion of vocalic intervals (i.e., vowels) within each sentence (%V; see Grabe & Low, 2002, for an alternate measurement scheme). Studies have revealed that although categorical divisions are useful, languages fall somewhat continuously along these dimensions (see Figure 2.1).
Research has demonstrated the importance of rhythmicity in early language processing. Newborn infants exposed to only a single language prenatally show greater interest in their native language than in an unfamiliar language from a different rhythmic class (Mehler et al., 1988; Moon, Cooper, & Fifer, 1993). Preferential attention to the native language shows an early effect of learning on language processing, either during prenatal
development or immediately after birth\textsuperscript{2}. Studies also show that monolingual neonates can discriminate two languages from different rhythmic classes even if both are unfamiliar but typically fail at discriminating languages within the same class (Ramus, Hauser, Miller, Morris, & Mehler, 2000; Mehler et al., 1988; Nazzi, Bertoncini, & Mehler, 1998; Ramus, 2002). These findings are understood as evidence that although language preference is learned through experience, the ability to discriminate languages from different rhythmic classes is an evolutionarily deep perceptual bias that operates independently of learning (Ramus, et al., 2000). Moreover, it has been asserted that the ability to discriminate languages is foundational to bilingual acquisition (Nazzi et al., 1998). No studies to date, however, have actually tested either language preference or language discrimination in neonates with prenatal bilingual exposure. Here, we provide the first empirical test of the hypothesis that the same initial perceptual biases and early learning mechanisms that underlie monolingual acquisition operate in the bilingual neonate to propel bilingual acquisition.

To test this hypothesis, we explored the earliest foundations of two capacities crucial to bilingual acquisition. We compared preference for (Study 1) and discrimination of (Study 2) English and Tagalog (languages from different rhythmic classes) in \textit{bilingual} newborns, whose mothers spoke both languages regularly during pregnancy, with those of \textit{monolingual} newborns, whose mothers spoke only English during pregnancy. Although it could be the case that infants only gradually develop the skills to negotiate a bilingual environment (Arnberg & Arnberg, 1985), our results demonstrate that from birth, the recognition and discrimination skills that support monolingual acquisition also support bilingual acquisition.

\textsuperscript{2} It is difficult if not impossible to separate the influence of prenatal experience from the possible effects of very early postnatal experience. However, given the much greater amount of prenatal as compared to postnatal listening, we have highlighted prenatal experience throughout this paper.
2.2 Study 1a

No previous studies have investigated language preference in bilingual neonates. While monolingual neonates orient more toward their native language than toward an unfamiliar language in preferential listening tasks, for optimal learning, infants growing up bilingual should orient to both of their native languages. To investigate the impact of prenatal experience on language preference at birth, we tested newborn infants for their preference for syllable-timed Tagalog (a major language of the Philippines; Bird, Fais, & Werker, 2005), relative to English, a stress-timed language (Ramus et al., 1999; see Figure 2.1). Two groups of neonates were tested: English monolinguals (whose mothers spoke only English during pregnancy) and Tagalog-English bilinguals (whose mothers spoke both English and Tagalog regularly during pregnancy). We expected that monolinguals would be significantly less interested in Tagalog than in English, as Tagalog was unfamiliar (Mehler et al., 1988; Moon et al., 1993). The previously untested prediction was that bilinguals would be interested in both of their native languages.

2.2.1 Method.

Testing was conducted at a maternity hospital in Vancouver, British Columbia, Canada, a multicultual city where English is the majority language but many other languages are widely used.³ Thirty newborn infants (0-5 days old), half from monolingual English backgrounds and half from bilingual Tagalog-English backgrounds (henceforth called Tagalog bilinguals) completed the study.⁴ Mothers of Tagalog bilinguals reported speaking each language 30% to 70% of the time.

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³ See Appendix 1 for University of British Columbia Research Ethics Board approval certificate for the studies reported in this paper.
⁴ Data were excluded from an additional 28 infants in Study 1 (preference), and 87 infants in Study 2 (discrimination) because of crying (12 preference/27 discrimination), falling asleep/stopping sucking (12/31), experimenter or technical error (3/3), spitting out the rubber nipple (1/5), high
Stimuli were sentences matched for pitch, duration, and number of syllables. They were recorded from native English and native Tagalog speakers and low-pass filtered to a cutoff of 400 Hz, to remove surface segmental cues while preserving rhythmicity. Infants were tested using a high-amplitude sucking-preference procedure, which capitalizes on newborns’ sucking reflex. Newborns sucked on a rubber nipple and were played a sentence contingently on producing a suck in the upper 80% of their sucking range, as calculated by the computer during an initial silent baseline minute. Infants were presented with 10 minutes of speech, alternating each minute between English and Tagalog. Four different English and four different Tagalog sentences were used, recorded from three native English and three native Tagalog speakers. The order of the two languages was counterbalanced. To assess preference, the number of high-amplitude sucks produced during Tagalog minutes versus English minutes was compared.

2.2.2 Results.

A preference score was computed for each infant, as the difference in the average number of high-amplitude sucks produced during Tagalog minutes minus those produced during English minutes (see Figure 2.2). One English monolingual and one Tagalog bilingual outlier, whose preference scores were more than 2 SDs from their group’s mean, were removed.\(^5\) Preliminary analyses suggested heterogeneity among group variances, Levene’s \(F(1, 26) = 4.87, p = .036\); therefore, subsequent analyses used Welch’s correction. This correction often yields noninteger estimates of degrees of freedom.

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\(^5\) Including these infants yielded the same pattern of results.
To determine whether the groups could be characterized as having significant absolute preference for one language over the other, two-tailed one-sample t tests were conducted, comparing infants' preference scores with zero. Monolingual English infants were significantly less interested in Tagalog than in English, $t(13) = -3.44, p = .004$. Tagalog bilinguals did not show a significant preference for either language, $t(13) = 1.76, p = .103$. To directly compare the performance of the two groups, a planned directional comparison
of infants’ difference scores was conducted. Relative to their interest in English, English monolinguals had significantly less interest in Tagalog than did Tagalog bilinguals, \( t(18.8) = 3.08, p = .003 \).

### 2.2.3 Discussion.

The results of this study demonstrate that prenatal bilingual exposure affects infants’ preferences. English monolingual newborns were less interested in Tagalog than in English, but Tagalog bilinguals were similarly interested in their two native languages. Bilinguals’ attention to both languages is consistent with their having learned about two languages prenatally.

A counter explanation consistent with these data would be that Tagalog bilinguals recognized neither language as native. Because bilinguals’ time is divided between two languages, their experience with each language may have been insufficient to have an effect on perception. The insufficient-experience explanation leads to a clear prediction: regardless of the particular native languages, any group of bilingual newborns will show the same pattern of language preference. Conversely, evidence that two groups of bilingual newborns demonstrate different patterns of preference would support the position that bilingual newborns have had sufficient experience to learn about each language prenatally.

### 2.3 Study 1b

To directly test the insufficient-experience explanation, we sought a second group of bilingual newborns to evaluate on their preference for Tagalog versus English. Because English was a common language to the two groups tested in Study 1a, it was necessary to find another group of bilinguals who had heard English prenatally. Chinese-English bilinguals were such a group that was available in our community.
Similarities and differences between Tagalog and Chinese make Chinese-English bilinguals an interesting test case. Both Chinese (Mandarin and Cantonese) and Tagalog have been classified within the larger typological category of syllable-timed languages (Bird et al., 2005; Lin & Wang, 2007; Mok, in press). But as shown in Figure 2.1, Tagalog and Chinese show rhythmical differences, and there is evidence that 4-month-old bilingual infants are sensitive to intraclass differences (Bosch & Sebastián-Gallés, 1997, 2001). Further, Chinese is characterized by lexical tone (perceptible by adults even in filtered speech; Fu, Zeng, Shannon, & Soli, 1998), whereas Tagalog is not. Overall, we expected that Tagalog would be somewhat, although not completely, familiar to the Chinese bilingual infants. Thus, because Tagalog is neither completely novel (as it is to English monolinguals) nor completely familiar (as it is to Tagalog bilinguals), we predicted that Chinese bilingual infants would show a preference intermediate to the preference shown by the two other groups and statistically different from each of them.

2.3.1 Method.

Fourteen neonates whose mothers spoke both English and Chinese (Cantonese, Mandarin, or in two cases both) regularly during pregnancy were tested for their preference for Tagalog versus English, in a procedure identical to that used in Study 1a.

2.3.2 Results and discussion.

The results demonstrated that Chinese bilingual neonates did not show an outright preference for either English or Tagalog, \( t(13) = -0.49, p = .63 \). As predicted, however, these infants showed a pattern of preference distinct from that of either English monolinguals or Tagalog bilinguals. Planned directional comparisons showed that their interest in Tagalog relative to English was greater than that of English monolinguals, \( t(25.5) = 1.89, p = .035 \), but less than that of Tagalog bilinguals, \( t(20.4) = 1.77, p = .046 \). Therefore, relative to their
interest in English, Chinese bilingual infants were less interested in Tagalog than were Tagalog bilingual infants (for whom Tagalog was native) but more interested in Tagalog than were English monolingual infants (for whom Tagalog shares few similarities with the native language). These results demonstrate that bilingual newborns’ language preference is affected by the specific languages they heard before birth, indicating that bilingual newborns have indeed learned about both their native languages prenatally.

2.4 Study 2

Study 1 demonstrated that by birth, bilingual neonates have already learned about their two languages and, like monolinguals, use this information to direct their attention. However, to successfully acquire the structures of two languages, bilingual infants must also separate and discriminate these languages. A possible interpretation of the results of Study 1a is that experience with two languages can overwrite the perceptual biases that facilitate language discrimination and that Tagalog bilingual neonates have no preference because they lump English and Tagalog into a broad class of familiar language sounds.

Previous research supports the idea that any newborn can discriminate two languages as long as the languages are from different rhythmic classes (Mehler et al., 1988; Nazzi et al., 1998; Ramus, 2002). However, systematic studies have not been conducted to date with bilingual newborns. Because monolinguals are familiar with only one language, discrimination of any particular language pair involves either discriminating a rhythmically familiar language from an unfamiliar one or discriminating two rhythmically unfamiliar languages. For bilingual infants, successful acquisition requires their discrimination of two familiar languages, a potentially challenging and as yet untested task.
2.4.1 Method.

To investigate whether newborns with prenatal bilingual experience discriminate their native languages, Study 2 tested 50 newborn infants for their discrimination of English and Tagalog in a high-amplitude sucking habituation procedure. As in Study 1a, newborns from a Tagalog-English bilingual background were compared with newborns from a monolingual English background.

Infants were habituated to either 4 English or 4 Tagalog low-pass filtered sentences (counterbalanced) until sucking declined, such that the number of high amplitude sucks across a two-minute window was at least 25% fewer than that produced in the previous minute. Infants habituated in an average of 7 minutes (range: 5-15; not different across groups, $F(2,47) = .49, p = .62$). At test, infants in the experimental group heard 2 novel sentences from a new speaker in the other language (N=32; 16 monolingual, 16 bilingual infants) for 4 minutes. To rule out spontaneous recovery (Jeffrey & Cohen, 1971), a control group (N=18; monolinguals) heard 2 novel sentences from a new speaker in the same language. Bilingual controls were not tested, as spontaneous recovery is not expected to differ across groups. If infants can discriminate the languages, then those in the experimental condition should show increased sucking at test, while those in the control condition should not.

2.4.2 Results and discussion.

Both English monolingual and Tagalog bilingual infants discriminated between the two languages (see Figure 2.3). The number of high-amplitude sucks was computed in three blocks: last two habituation minutes, first two test minutes, and second two test minutes. Preliminary analyses showed no effects or interactions with test order (English first vs. Tagalog first). A mixed 3 (block) × 2 (condition: control, experimental) analysis of variance (ANOVA) showed a significant Block × Condition interaction, $F(2, 96) = 3.20, p = .045$. A
follow-up repeated measures ANOVA showed that in the control group, sucking did not differ as a function of block, $F(2, 34) = 2.04, p = .15$. In the experimental group, a similar ANOVA with an additional factor of exposure group (English monolingual, Tagalog bilingual) showed a significant effect of block, $F(2, 60) = 4.64, p = .013$, but no Block × Exposure Group interaction, $F(2, 60) = 0.40, p = .67$. Planned directional $t$ tests compared sucking in the final habituation block with the average across the four test minutes (both test blocks). Both English monolingual infants, $t(15) = 2.00, p = .032$, and Tagalog bilingual infants, $t(15) = 1.99, p = .033$, showed a significant recovery of sucking during test. Tagalog bilingual infants, then, were still able to discriminate their two languages, despite having shown similar preference for the languages in Study 1a.
Figure 2.3 Number of high amplitude sucks per minute across experimental blocks for the control and experimental (monolingual English and Tagalog bilingual exposure) groups in Study 2 (discrimination).

2.5 General discussion

Previous work with bilingual infants has shown that 4-month-olds can discriminate their languages auditorily (Bosch & Sebastián-Gallés, 1997) and visually (Weikum et al., 2007). The current work reveals that language discrimination in bilinguals is robust at birth
and that language preference at birth reflects previous listening experience. Monolingual newborns’ preference for their single native language directs listening attention to that language. Bilingual newborns’ interest in both languages helps ensure attention to, and hence further learning about, each of their languages.

This study investigated neonates who were learning rhythmically distinct languages. Still unanswered is whether the same sensitivity to rhythm can also support infants acquiring two languages from the same rhythmic class. The differential preference for Tagalog by Tagalog-English bilinguals in comparison with Chinese-English bilinguals hints that bilingual neonates have some sensitivity to intraclass rhythmic differences or to other differences between language pairs in the same rhythmic class. Further research is required to directly test these possibilities.

In sum, these findings show that from the very beginning, the same perceptual and learning mechanisms that support monolingual acquisition are also available to support bilingual acquisition. Moreover, our results confirm that infants exposed to two languages throughout gestation have already begun the process of bilingual acquisition at birth.
2.6 References


The development of associative word learning in monolingual and bilingual infants

3.1 Introduction

Even before their second birthday, infants have gained considerable expertise in word learning. Around age 1½, English-learners become sensitive to syntactic cues that differentiate count nouns and proper names (Bélanger & Hall, 2006), can use word learning heuristics to disambiguate a novel noun in the presence of multiple referents (Byers-Heinlein & Werker, 2009; Halberda, 2003; Markman, Wasow, & Hansen, 2003), and consider statistical information when establishing the likely referent of a word (Smith & Yu, 2008; Vouloumanos & Werker, 2009). Even in their first year, infants have growing receptive vocabularies (Fenson, Marchman, Thal, Dale, & Bates, 2007), and can demonstrate comprehension of highly frequent words in experimental procedures (Tincoff & Jusczyk, 1999). These studies reveal a nascent ability to associate words and referents. This skill is foundational to referential word knowledge - the understanding that a word can stand for a concept (Nazzi & Bertoncini, 2003; Oviatt, 1980; Waxman & Gelman, 2009).

To what degree is infants’ burgeoning word learning expertise influenced by the nature of their language environment? On one hand, cross-linguistic and bilingual studies reveal striking similarity in the age of onset, and the nature of children’s early productions (Holowka, Brosseau-Lapré, & Petitto, 2002; Caselli et al., 1995; Pearson, Fernández, & Oller, 1993). On the other hand, cross-language differences have been reported in such diverse areas as the prevalence of nouns in children’s early vocabularies (Tardif, 1996; Tardif, Gelman, & Xu, 1999), preschoolers’ extension of novel nouns (Imai & Gentner, 1997; Yoshida & Smith, 2001), the detection of mispronunciations in familiar words (Ramon-
Casas, Swingley, Sebastián-Gallés, & Bosch, 2009), and in bilingual children’s use of word learning strategies such as mutual exclusivity (Byers-Heinlein & Werker, 2009; Davidson, Jergovic, Imami, & Theodos, 1997; Davidson & Tell, 2005; Houston-Price, Caloghiris, & Raviglione, 2010; but see also Frank & Poulin-Dubois, 2002).

While findings with preschoolers suggest that the input language can influence word learning, relatively little is known about whether similar differences are also present in infancy as most experimental infant work has studied monolingual English-learners (e.g. Hollich et al., 2000; Houston-Price, Plunkett, & Harris, 2005; Pruden, Hirsh-Pasek, Golinkoff, & Hennon, 2006; Schafer & Plunkett, 1998; Schafer, 2005; Woodward, Markman, & Fitzsimmons, 1994; Woodward & Hoyne, 1999). To address this gap in the literature, we turn to a population which can be particularly revealing of the influence of early language environment: infants growing up bilingual.

### 3.1.1 Early bilingualism.

Bilingual infants navigate a linguistic world that contains two languages; they must learn two phonetic inventories, two words for each referent, and two grammars. Perceptual cues in the input facilitate the acquisition of two languages, and young bilinguals show sensitivity to and learning from these cues, for example recognizing and discriminating their languages both auditorily and visually by 4 months (Bosch & Sebastián-Gallés, 1997; Bosch & Sebastián-Gallés, 2001; Weikum et al., 2007). Even newborns who have been exposed to two rhythmically distinct languages prenatally can discriminate sentences across their languages (Byers-Heinlein, Burns, & Werker, 2010; see Chapter 2).

Bilingual infants do sometimes show unique developmental trajectories. For example, the timing of phonetic development differs from monolinguals for some contrasts (Sebastián-Gallés & Bosch, 2002, 2009;), but not others (Burns, Yoshida, Hill, & Werker, 2007; Sundara, Polka, & Molnar, 2008). Phonotactic development may also differ,
interacting with language dominance (Sebastián-Gallés & Bosch, 2002). Outside the language domain, early bilingualism may improve some cognitive abilities in infancy, particularly inhibition (Kovács & Mehler, 2009a, 2009b).

### 3.1.2 Associative word learning.

Despite increasing interest in and understanding of bilingual language development, little work has studied associative word learning abilities in young bilinguals. Infants’ ability to make word-object associations is thought to be the first word learning skill to emerge ontogenetically, building on infants’ categorization of objects, segmentation of the speech stream, and recognition of word forms (e.g. Golinkoff & Hirsh-Pasek, 2006; Hollich et al., 2000; Oviatt, 1980; Werker, Cohen, Lloyd, Casasola, & Stager, 1998). Some researchers argue that associative information is the primary means by which the novice word learner establishes word-object links (Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002), and that associative regularities could give rise to word learning constraints, such as the shape bias and fast mapping (Smith, Jones, Yoshida, & Colunga, 2003). Although others argue that associative word learning is not the same as referential word learning and cannot lead to its discovery (Booth & Waxman, 2003; Waxman & Gelman, 2009; Woodward, 2004), there is a consensus that associative word learning is an essential component of early word learning.

Given the centrality of associative word learning, it is important to know whether this skill emerges on the same developmental schedule in monolingual and bilingual infants. Yet, if the ability to form associations is such a powerful word learning tool, is there any reason to suspect that this capacity differs across infants? There are indications that, in the initial stages of word learning, the ability to form word-object associations is mutable even in monolingual English-learning infants, leaving open the possibility that the nature of the early language environment could affect early word learning. In the laboratory, English-
learners under 12 months-of-age require explicit cues to establish word-object associations, such as temporal synchrony between an object’s movement and its auditory label (Gogate & Bahrick, 1998), or a highly salient target object (Pruden et al., 2006; although see Curtin, 2009, for a study in which 12-month-olds succeeded without such cues). At 13-14 months, associations seem to be best learned in a rich context, with speaker-listener interactions, referential cues, and syntactic information (Fennell & Waxman, in press; Woodward et al., 1994).

Conversely, just as increased cognitive capacities and contextual cues support infants in word-object associative tasks, the more complex associative environment of the bilingual could hinder this ability. By complex, we mean that bilingual infants need to associate more than one basic-level label with any object (one label from each language). This undoubtedly increases the variability in their associative statistics and could necessitate the revision of established associations. Both of these factors may increase the developmental time needed to concretely establish associations and decrease bilingual infants’ confidence in established associations.

3.1.3 The Switch task for studying associative word learning.

We know of only two studies to date which have contrasted associative word learning abilities in monolingual and bilingual infants. Both studies (Fennell, Byers-Heinlein, & Werker, 2007; Mattock, Polka, Rvachew, & Krehm, 2010) used a habituation word learning paradigm called the Switch task (Werker et al., 1998).

In the original development of the Switch task with monolingual English-learners, Werker and colleagues (1998) habituated infants between 8 and 14 months to two word-object pairings shown on a television: a plastic dog paired with the word lif and a toy truck paired with the word neem. At test, infants saw one trial with a familiar pairing from habituation (Same trial), and one trial with a novel pairing, like the truck paired with lif
(Switch trial). If infants were able to encode the word, the object, and the link between the two, they were expected to look longer at the more novel Switch trial than during the Same trial. The results showed that only the 14-month-olds looked longer at the Switch trial compared to the Same trial, suggesting that infants younger than this cannot associate words and objects in this task.

Considerable research has also been conducted using the Switch task to investigate minimal pair word learning in monolinguals (e.g. Curtin, 2009; Dietrich, Swingley, & Werker, 2007; Fennell & Werker, 2004; Pater, Stager, & Werker, 2004; Rost & McMurray, 2009; Stager & Werker, 1997; Thiessen, 2007; Werker et al., 2002; Werker, Fennell, Corcoran, & Stager, 2002). Minimal pair words are those words that differ in a single phonological element (e.g. "bat" and "pat"). Minimal pair word learning has been of particular interest because it requires infants to apply their phonetic sensitivities while associating a word and its referent. Fennell, Byers-Heinlein, & Werker (2007) extended the study of minimal pair word learning to bilingual infants. They tested bilingual infants on their ability to associate minimally different words "bih" and "dih" with two unfamiliar objects. While monolinguals can learn this association by 17 months (Pater et al., 2004; Stager & Werker, 1997; Werker et al., 2002; Werker et al., 2002), bilinguals showed evidence of learning these words only at 20 months (Fennell et al., 2007).

In a related study, Mattock and colleagues (2010) tested English-French bilinguals, French monolinguals, and English monolinguals, on their ability to learn the minimal pairs bos and gos, also using the Switch task. Bilinguals succeeded at 17 months when tokens were pronounced in both a French and an English manner. In contrast, both French and English monolinguals failed at 17 months when tokens were mixed between French and English pronunciations, but succeeded when tokens matched their language-learning
context (i.e. French monolinguals succeeded with French-pronounced tokens, but failed with English-pronounced tokens).

The results of these studies suggest that, at least for minimal pair words, monolinguals and bilinguals show success in associative word learning at different ages and under different conditions. One possibility is that these differences are specific to minimal pair word learning, originating from the difficulty bilinguals have navigating their more complex phonetic space (Bosch & Sebastián-Gallés, 2003; Sebastián-Gallés & Bosch, 2009; Sundara, Polka, & Genesee, 2006; Yoshida, Fennell, Swingley, & Werker, 2009), from a later emergence of stable phoneme categories that could guide word learning (Curtin, Werker, & Byers-Heinlein, under review; Werker, Byers-Heinlein, & Fennell, 2009; Werker & Curtin, 2005), and/or from the greater phonetic variability inherent to bilinguals' language experience than that of monolinguals (Mattock et al., 2010). However, an alternate explanation exists: the developmental dissimilarity between monolingual and bilingual minimal pair word learning may stem from a difference in the more general ability to associate words and objects, rather than being specific to minimal pair words. Because bilingual infants have been tested on minimal pair associative word learning, but not yet on associative word learning using more distinct words, we do not know whether the difficulty lies is paying attention to fine phonetic detail or in the more fundamental readiness to pair words and concepts.

We know of no laboratory studies that have compared basic associative word learning abilities in monolingual and bilingual infants. A study comparing these infants’ performance on the learning of dissimilar-sounding words is therefore critical, both to interpreting the results of studies of minimal pair word learning, and to understanding whether and how early language experience affects fundamental mechanisms that support associative word learning. The current study therefore tested monolingual and bilingual
infants on their ability to learn dissimilar-sounding words *lif* and *neem* at both 12- and 14-months-of-age, in order to straddle the age of known success in monolinguals. Monolinguals and bilinguals should succeed and fail at the same ages if the ability to associate a word and object is a robust mechanism that develops with little regard to the specifics of the early language environment. However, it is also possible that, just as in other language areas, monolinguals and bilinguals will have different developmental trajectories due to the differences in the complexity of their language environments.

### 3.2 Method

#### 3.2.1 Participants.

Ninety-seven infants completed the study. These infants fell into 4 groups (12 females per group) based on age and language background: 12-month-old monolinguals (N=25), 12-month-old bilinguals (N=24), 14-month-old monolinguals (N=24), and 14-month-old bilinguals (N=24). Twelve-month-olds had a mean age of 12m17d (range: 11m22d to 13m8d), and 14-month olds had a mean age of 14m17d (range: 13m27d to 15m8d). An additional 36 participants were excluded because of crying/fussiness (23), technical error (7), and parental interference (6).

Monolinguals came from English-speaking homes, and had not received any regular exposure to a non-English language. Bilinguals came from homes where English as well another language (20 different languages were represented) had been spoken regularly since the infant’s birth. Bilinguals heard each language between 25% and 75% of the time (Pearson, Fernández, Lewedeg, & Oller, 1997), measured via the Language Exposure Questionnaire (Bosch & Sebastián-Gallés, 1997). On average, bilinguals heard English 47% of the time (range 26% to 73%), and their non-English language 51% of the time (range 28% to 74%). A few infants heard a small amount of a third language.
3.2.2 Stimuli.

Auditory stimuli were recorded by a female native English speaker who produced seven tokens each of three nonsense words, lif, neem, and pok, in an infant-directed manner. These were chosen to be maximally phonetically different, with no vowel or consonant overlap.

Visual stimuli used during habituation were colourful images of a clay crown-shaped object (Figure 3.1. A) and a plastic molecule-shaped object (Figure 3.1. B), filmed moving across a black background. A spinning waterwheel object was used during the pretest and posttest (Figure 3.1. C). These objects were identical to those used in several previous studies (e.g. Fennell et al., 2007; Werker et al., 2002).

Figure 3.1. Objects used for visual stimuli. A) Crown-shaped object labeled lif B) Molecule-shaped object labeled neem C) Waterwheel object used for pretest and posttest labeled pok.

Audio and visual stimuli were combined to create 20-second trials. The audio tokens were presented approximately 2 seconds apart, and looped such that the first three tokens were played twice. Visual stimuli were displayed simultaneously, although not synchronously, with the audio (Gogate & Bahrick, 1998).

3.2.3 Apparatus.

Testing took place in a dimly lit, sound-attenuated room. A television monitor displayed the visual stimuli, and hidden speakers on either side played the sound at
68±5db. A digital video camera recorded infants response for later off-line coding. In an
adjacent room, the experimenter controlled the study with computer running Habit 2000
(Cohen, Atkinson, & Chaput, 2000), and monitored the infants’ looking behavior online via a
closed-circuit television.

3.2.4 Procedure.

Infants were tested using the Switch procedure (Werker et al., 1998). Infants sat on
their parent’s lap throughout the study, while their parent listened to masking music over
headphones. All infants started with a pretest trial during which the waterwheel object was
displayed while the pok tokens played. Next, infants were habituated to two word-object
pairings: the crown-shaped object with lif, and the molecule-shaped object with neem. Trials
were presented in blocks of four; each pairing was presented twice per block, yielding six
combinations (e.g. ABBA, AABB) that were presented in a quasi-random order. Infants saw
these pairings until they habituated, such that their looking time over the most recent trial
block was 65% of that during the block when the infant looked the most. Infants who did
not habituate within 24 trials proceeded directly to the test phase.

After habituation, infants saw two test trials presented in one of 8 possible test
orders, counterbalancing which trial type occurred first (Same, Switch) and word-object
pairings. On the Same test trial, infants saw a familiar pairing, (e.g. molecule-neem). On the
Switch test trial, infants saw an unfamiliar pairing (e.g. molecule-lif). If infants were able to
associate the word and object, then the Switch trial would be novel. However, if infants
learned the audio and video stimuli without associating the two, then both trial types would
be equally familiar. A posttest consisting of the waterwheel paired with pok was used to
ensure that infants had not lost interest in the task.

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7 See Appendix 2 for University of British Columbia Research Ethics Board approval certificate for the
studies reported in this paper.
Videotapes were digitized and test trials were re-coded offline by a highly trained coder who examined infants’ looking frame-by-frame, with high reliability ($r=.97$). All analyses of test trials reported here were conducted with offline-coded data.

### 3.3 Results

Infants completed the habituation phase in 16 trials on average, with no significant effects of age or language background on this measure. Sixteen of the infants did not reach habituation within 24 trials. A t-test comparing looking time during the first 4-trial block to looking time in the final 4-trial block confirmed that the infants had habituated as a group, $t(92)=14.43$, $p<.0005$. Another t-test showed that infants’ looking time recovered during the post-test as compared to the final four habituation trials, $t(92)=21.90$, $p<.0005$. Thus, infants had not generally lost interest in the task.

Identification of outliers was performed by calculating a difference score (looking during the Switch trial minus looking during the Same trial) for each infant, and excluding those infants whose scores were more than 2.5 standard deviations away from the mean difference score across infants. Three outliers were excluded from further analyses: 1 14-month monolingual, 1 14-month bilingual, and 1 12-month bilingual.

The main question of interest was whether infants showed differential looking across the test trials, and whether their performance differed as a function of language background. Accordingly, a 2 (trial type: Same, Switch) x 2 (language background: monolingual, bilingual) mixed ANOVA was performed separately for each age group. Gender and trial order were not included, as preliminary analyses had shown no significant effects or interactions.

For 12-month-olds, no significant effect of trial type was found, $F(1, 46)=.017$, $p=.90$, $\eta_p^2 <.0005$. This indicated that 12-month-old infants displayed similar looking during Same and Switch test trials, thereby failing to demonstrate successful association of the words
and objects. Further, trial type did not interact with language background, \(F(1, 46)=.073, p=.788, \eta_p^2 = .002\), indicating equivalent performance for monolinguals and bilinguals. However, there was a marginally significant main effect of language background, \(F(1,46)=3.15, p=.082, \eta_p^2 = .064\), reflecting that 12-month-old bilinguals looked longer across both types of test trials (\(M_{\text{Same}}=10.74, SD_{\text{Same}} = 4.64, M_{\text{Switch}}=10.82, SD_{\text{Switch}}=4.64\)) than did monolinguals (\(M_{\text{Same}}=8.93, SD_{\text{Same}}= 4.27, M_{\text{Switch}}=8.69, SD_{\text{Switch}}=3.97\)), see Figure 3.2.

**Figure 3.2** Study results for 12- and 14-month-old monolinguals and bilinguals.

Fourteen-month-olds did demonstrate learning of the word-object associations, looking significantly longer to the Switch than to the Same trial, \(F(1,44)=4.22, p=.046, \eta_p^2 = .088\). There was no significant main effect of language background, \(F(1,44)=.94, p=.34, \eta_p^2 = .02\), nor interaction between trial type and language background, \(F(1, 44)=.21, p=.648, \eta_p^2 = .005\). Indeed, a similar pattern of looking was demonstrated by bilinguals (\(M_{\text{Same}}=8.93, SD_{\text{Same}}= 4.98, M_{\text{Switch}}=10.54, SD_{\text{Switch}}=4.34\)) and monolinguals (\(M_{\text{Same}}=10.45, SD_{\text{Same}}= 5.09, M_{\text{Switch}}=11.47, SD_{\text{Switch}}=4.90\)), see Figure 3.2.
3.4 Discussion

The current study investigated monolinguals’ and bilinguals’ ability to associate a novel word with a novel object at 12 and 14 months. Monolinguals and bilinguals showed an identical developmental pattern. Regardless of language background, infants successfully associated the words lif and neem with different objects at 14 months, but failed at 12-months-of-age.

On the one hand, this finding is consistent with studies showing that bilinguals have similar vocabulary sizes as monolinguals when words from both languages are taken into account (De Houwer, Bornstein, & De Coster, 2006; Junker & Stockman, 2002; Pearson et al., 1993). Such a parallel would only be seen if monolinguals and bilinguals have similar abilities to associate words and their referents. On the other hand, this result is surprising given previous discrepancies between the two groups in associative word learning (Fennell et al., 2007; Mattock et al., 2010) and familiar word recognition (Ramon-Casas et al., 2009), particularly with regards to minimal pair words. These results therefore support the growing consensus that bilinguals do not differ from monolinguals in the development of fundamental language learning abilities (Mattock et al., 2010; Werker & Byers-Heinlein, 2008). Rather, differences reported in previous minimal pair studies likely stem from specific aspects of the bilingual experience, for example the more complicated phonetic space that bilinguals must navigate, and/or the increased variability in phonemes that they hear.

Although research with other language groups will be needed to replicate and extend this finding, the current results suggest that the fundamental ability to link sound and objects is robust across different early language environments. Even though bilinguals are exposed to a more complex associative environment than monolinguals are, where objects tend to have two basic-level labels, early differences seen in the use of some word
learning heuristics (e.g. Byers-Heinlein & Werker, 2009; Houston-Price, Caloghiris, & Raviglione, 2010) are absent in the more foundational skill of associative word learning. Like monolinguals, 14-month-old bilinguals can quickly and efficiently link a word and its referent in a stripped-down and highly controlled laboratory task.

In the 12-month-old group, bilinguals looked longer during both test trials than monolinguals, a finding that approached significance. This may indicate that bilingual infants attend to and interpret some aspects of speech differently from monolinguals, an idea recently put forth by Sebastián-Gallés (2008) to explain differences between these groups in some studies of phonetic discrimination. However, any interpretation of this result is complicated by equal looking times seen across both groups of 14-month-olds, and previous findings wherein bilinguals had shorter overall looking times than monolinguals (i.e., Fennell et al., 2007).

### 3.4.1 Word recognition in bilingualism.

Our results can also help to shed light on findings related to bilinguals’ knowledge of familiar words. Two studies used Event Related Potentials (ERPs) to investigate bilingual infants’ brain responses to already-known word forms. In a study with Welsh-English bilingual infants of 9 and 12 months-of-age, ERPs to both English and Welsh words were similar to ERPs that English-learning infants showed to English words. The pattern seen in these two groups differed, however, from the pattern shown by Welsh monolinguals in response to Welsh words (Vihman, Thierry, Lum, Keren-Portnoy, & Martin, 2007). In another study, 2-year-old Spanish-English bilinguals showed a similar ERP response as monolinguals to words in their dominant language, but showed a different pattern from words in their non-dominant language (Conboy & Mills, 2006).

The current findings suggest that any differences between monolinguals and bilinguals in word form recognition do not lie in the ability to form an initial association
between word and object. Thus, it follows that differences between monolinguals and bilinguals in ERPs to known words may derive from different types of experience with these words rather than differences in encoding between the dominant and the non-dominant language. For example, bilinguals might hear dominant language words more frequently than non-dominant language words, and likely hear any particular word less frequently than a monolingual, which could explain reported differences in ERPs. A study that recorded ERPs to word forms taught in a controlled laboratory setting, rather than relying on the child’s own naturalistic experience, could help to test this idea, and further show when and how word learning differs as a function of language experience.

3.4.2 The role of object familiarity in word learning.

Our results appear to replicate those of Werker and colleagues (1998) which show that monolingual infants can learn dissimilar-sounding words in the Switch task as early as 14 months. However, while our study used the same procedure and auditory stimuli as Werker et al. (1998), we used novel, unfamiliar objects instead of pictures of familiar objects (a plastic dog and a toy truck).

Although the role of object familiarity was not the motivating question behind the studies presented here, our study does provide a test of this variable, which has seldom been explicitly manipulated in experimental studies (Houston-Price et al., 2005). Two exceptions are a study showing that children are more likely to link a novel label to a familiar object without a known label than with an unfamiliar object (Graham, Turner, & Henderson, 2005), and a study suggesting that object familiarity might facilitate minimal-pair word learning (Fennell & Werker, 2004). Given that previous studies have indicated that unfamiliar objects can impede word learning while in our study they did not, the role of object familiarity in early word learning could prove to be a fruitful avenue of future research.
3.4.3 Conclusion.

Between 12 and 14 months-of-age, infants cement an ability to associate a word and its referent in a laboratory task. Monolingual and bilingual infants showed an identical developmental trajectory, succeeding at our task at 14 months, and failing at 12 months. That infants from two very different language backgrounds achieve associative word learning on the same schedule reveals that this learning mechanism is highly robust, and little-influenced by the specific nature of the early language environment. Our findings suggest that reported differences in acquisition between monolinguals and bilinguals, particularly in older infants and children, likely stem from differences in the type and frequency of information available in the bilingual environment, rather than from differences in the mechanisms that support such learning. Our results can help to explain parallels in vocabulary acquisition between monolingual and bilingual infants, and provide a foundation for future studies of word learning in bilinguals.
3.5 References


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4 Monolingual, bilingual, trilingual: Infants’ language experience influences the development of a word-learning heuristic

4.1 Introduction

A hallmark of children’s language development in the second year of life is their emerging ability to rapidly learn new words. One factor that likely contributes to rapid word learning is children’s capacity to infer the meaning of new words in underspecified contexts. For example, in the presence of a cup and an unfamiliar object such as a garlic press, children tend to associate a novel word like “zav” with the garlic press rather than with the cup (Markman & Wachtel, 1988). This heuristic of mapping a novel word onto a novel object is known as disambiguation (Merriman & Bowman, 1989). Disambiguation is often understood as the product of a word-learning constraint, one of many biases that allow children to limit the scope of plausible referents that they consider for the meaning of a novel word. Investigating how such constraints operate and where they come from is foundational to understanding the feat of lexical acquisition.

Most of the research to date investigating disambiguation has focused on children’s underlying motivation for mapping the novel noun onto the novel object. Several accounts posit a socio-pragmatic origin of this heuristic. Clark, for example, has proposed that children understand that different words come from different underlying intentions (1987; 1990). This gives rise to the principle of contrast, whereby children assume that different words must contrast in meaning. Similarly, Diesendruck and colleagues have suggested that disambiguation comes from pragmatic understanding. Children infer that a novel word

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8 A version of this chapter has been published. Byers-Heinlein, K., & Werker, J.F. (2009). Monolingual, bilingual, trilingual: Infants’ language experience influences the development of a word learning heuristic. Developmental Science, 12(5), 815-823. The data from the monolingual and bilingual infants in Study 1 were submitted in partial requirement for the degree of Master of Arts, awarded in 2006 to Krista Byers-Heinlein.
applies to a novel object (or one without a known name) because, had a particular speaker wanted a familiar object nameable by the child, that speaker would have used the conventional name (Diesendruck & Markson, 2001).

Other accounts of disambiguation are conceptual rather than social in nature. Markman and colleagues have suggested that disambiguation is a manifestation of the larger principle of mutual exclusivity, a “default assumption” that each object should have one basic-level label (Markman & Wachtel, 1988; Markman, 1992). Under the mutual exclusivity account, children show disambiguation because they first reject the nameable object as a referent for the new label, and then search for a novel object. Another proposal, the Novel-Name Nameless Category assumption (N3C; Mervis & Bertrand, 1994; Mervis, Golinkoff, & Bertrand, 1994) suggests that children disambiguate novel nouns because they are motivated to find a name for each object.

The question of how disambiguation first develops has received considerably less attention than investigations of children’s underlying motivation for the heuristic. Word learning and disambiguation do not develop synchronously: instead infants’ first understanding of highly frequent words such as “mommy” and “daddy” can be seen as early as 6 months (Tincoff & Jusczyk, 1999), while disambiguation appears later, between 16 and 18 months-of-age (Halberda, 2003; Markman, Wasow, & Hansen, 2003). Why is disambiguation unavailable at the onset of word learning? Different accounts of disambiguation provide different hypotheses. Socio-pragmatic accounts imply that children must achieve a certain level of socio-pragmatic understanding before they can show disambiguation, and this may not occur until well after their first birthday. The N3C account proposes that children must learn sufficient words in order to have the conceptual insight that each object should have a name (Mervis & Bertrand, 1994; Mervis et al., 1994). The mutual exclusivity account remains agnostic as to the origins of the constraint, and why it
emerges when it does. As Markman and colleagues have stated, "Whether and what kinds of exposure to linguistic input are relevant to working out this assumption remains an open question" (Markman et al., 2003, p. 272).

Here we test the possibility that language experience contributes to the development of disambiguation. The current studies take a cross-linguistic approach by comparing disambiguation in infants learning a single language to disambiguation in those learning multiple languages. Multilingual children are of particular theoretical interest, as they must learn a basic-level label in each of their languages for each object (one in each language), in apparent contradiction to constraints such as mutual exclusivity. Several studies of preschoolers and school-aged children have found that bilinguals show a weaker tendency to disambiguate novel nouns than monolinguals do (Davidson, Jergovic, Imami, & Theodos, 1997; Davidson & Tell, 2005; but see also Frank & Poulin-Dubois, 2002; Merriman & Kutlesic, 1993). Reported differences could originate in the initial development of disambiguation, or might come about as children gain increased social and linguistic experience during their preschool years. A comparison of monolingual and multilingual infants near the onset of the use of disambiguation could disentangle these two possibilities. If disambiguation differs between monolinguals and multilinguals from the get-go, this would provide strong evidence that language experience influences the development of disambiguation, and not just its later use.

We used a preferential looking-while-listening paradigm (Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998; Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Halberda, 2003) to test infants between 17 and 18 months old, the age when disambiguation is first shown in monolingual infants (Halberda, 2003; Markman et al., 2003; Mervis & Bertrand, 1994). Participating infants were all of the same chronological age, but differed with respect to their early language experience: infants grew up in either monolingual, bilingual, or
trilingual homes. Different accounts of disambiguation and its developmental origins yield different predictions about the relative performance of each group. If disambiguation emerges on a maturational timetable, infants should show similar performance on a disambiguation task regardless of language background. If the development of disambiguation is related to socio-pragmatic competence, then there is no particular reason to predict any differences between the groups as all would have had a similar amount of social experience. If language experience itself influences the development of disambiguation, then markedly different types of early experience might change the developmental timetable of disambiguation. In such a case, an examination of factors that predict infants' success in disambiguation, such as vocabulary size and the number of languages being learned, might provide important clues as to how disambiguation develops.

4.2 Study 1

4.2.1 Method.

4.2.1.1 Participants.

Forty-eight infants participated in Study 1, 16 each from monolingual, bilingual, and trilingual backgrounds. Half in each group were female. They ranged in age from 17m8d to 18m20d, and mean ages for the monolingual, bilingual, and trilingual groups respectively were 17m28d, 17m29d, and 18m1d. Eleven additional infants were tested but excluded due to restlessness (7), crying (2), disinterest in the procedure (1), and parental report of poor vision (1).

4.2.1.2 Language background.

Monolingual infants came from English-speaking homes, and their parents reported that they had not received any systematic exposure to a language other than English.
Multilingual infants had been exposed to English as well as either one other (bilinguals) or two other (trilinguals) languages in the home since birth. The non-English languages reported in the sample were diverse, including 22 different languages (see Appendix 3 for full details of multilingual infants’ language backgrounds). Exposure to each of the multilinguals’ languages was measured by the Language Exposure Questionnaire (Bosch & Sebastián-Gallés, 1997). For bilingual infants, a minimum of 25% exposure to each language was set as an inclusion criterion (Pearson, Fernández, Lewedeg, & Oller, 1997), and bilinguals heard a mean of 48% English (range: 27 to 70%), and 52% of their other language (range: 29 to 73%). For trilingual infants, perfectly balanced exposure would result in hearing each language 33% of the time. Therefore, for trilinguals we accepted a more relaxed minimum exposure to each language. On average, trilinguals heard English 37% of the time (range: 19 to 55%), and each of their two other languages 32% of the time (range: 19 to 55%).

4.2.1.3 Vocabulary measure.

Estimates of infants’ English vocabulary size were obtained by asking parents to complete the Words and Gestures form of the MacArthur-Bates Communicative Development Inventory (CDI; Dale & Fenson, 1996; Fenson, Marchman, Thal, Dale, & Bates, 2007), which has shown high validity in at least one bilingual sample (Marchman & Martinez-Sussman, 2002). For multilingual infants, parents were asked to complete the form with respect to only their child’s English vocabulary, and when possible, the caregiver who spoke English most often with the infant filled out the form. CDI data could not be collected for bilingual and trilingual infants’ non-English languages due to the unavailability of versions of the CDI for many of the languages represented. Vocabulary data were not available for two monolinguals, one bilingual, and one trilingual, because their caregivers failed to return a completed form. Reported English receptive and productive vocabulary
sizes were highest for monolinguals, and lowest for bilinguals, with the trilinguals between the other two groups (See Table 4.1).

**Table 4.1.** English CDI scores for infants in Study 1

<table>
<thead>
<tr>
<th></th>
<th>Receptive Vocabulary</th>
<th>Productive Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Monolinguals</td>
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<td>66</td>
</tr>
<tr>
<td>Bilinguals</td>
<td>156</td>
<td>72</td>
</tr>
<tr>
<td>Trilinguals</td>
<td>202</td>
<td>118</td>
</tr>
</tbody>
</table>

**4.2.1.4 Stimuli.**

Visual stimuli consisted of four brightly-colored objects, three familiar (ball, car, and shoe) and one novel. The novel object was a slightly modified version of a phototube from the TarrLab Object DataBank (1996). The objects were presented on a black background in consistent pairs: car-ball and phototube-shoe. The objects appeared in different colors on different trials to maintain infant interest, and to ensure generalization across different-colored exemplars of the same object category. Sample stimulus pairs are shown in Figure 4.1.

**Figure 4.1** Sample stimulus pairs. (a) Car-ball pair (b) Phototube-shoe pair.

Auditory stimuli were recorded by a female native English speaker who spoke in an infant-directed manner. The stimuli consisted of three labels that named the familiar objects- “ball”, “car”, “shoe”, and one label that named the novel phototube object – “nil.”
Although *nil* does have meaning for English-speaking adults, its infrequent use and abstract meaning make it unlikely that infants are familiar with this word.9 Each label was recorded in isolation, and with three carrier phrases, “Look at the ___”, “Find the ___”, and “Where is the ___”. For each trial, the label was presented once embedded in a carrier phrase (chosen quasi-randomly), and again in isolation (e.g., “Look at the ball! Ball!”).

To ensure that infants were likely to know the familiar words used in this study, we examined infants’ reported comprehension on the corresponding MCDI items. Comprehension within each language exposure group of “ball”, “car”, and “shoe” ranged from 80-100%. Therefore across all three groups, the vast majority of infants understood these words.

### 4.2.1.5 Apparatus.

Data were collected using a Tobii 1750 eye tracking system with the following components: a monitor that both presented the stimuli and recorded infant eye-gaze, and a PC computer running the Tobii Clearview software program that controlled the stimulus presentation and collected the eye tracking data. Light-emitting diodes built into the monitor generated invisible infrared light, which shined on the infant’s face. A high-resolution camera built into the monitor collected eye-gaze data based on the light reflection off the infant’s cornea relative to the pupil.

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9 It is also relevant whether “nil” was a word known to multilingual infants in a language other than English. No parents of participants in the study reported that their infants knew a meaning for the word “nil” in any language. Further, “nil” is either phonotactically illegal or is a non-word in the most frequent languages in our sample: French, Cantonese, Mandarin, Spanish, Tagalog, Vietnamese, and Japanese.
4.2.1.6 Procedure.

The study was conducted in a dimly lit, sound-attenuated room. Infants sat on their parent’s lap, approximately 60 cm away from the eye tracking monitor.\textsuperscript{10} Loudspeakers were located on either side of the monitor, hidden from view by a black cardboard panel. To avoid influencing the infant during the study, parents wore a blindfold or closed their eyes. The experimenter controlled the study from a computer and a closed-circuit TV monitor, out of sight of the infant. Prior to the study, a five-point infant calibration routine calibrated the eye tracker to the infant’s eyes.

Each session started with a warm-up trial, during which a spinning waterwheel appeared sequentially on each side of the monitor. Following the warm-up, infants were presented with experimental trials. On each trial, the object pair first appeared in silence on the monitor for 3 seconds, so that infants’ baseline preference for each object could be measured. The test phase of the trial immediately followed the baseline phase, when an auditory stimulus was played that named one of the objects (e.g., “Look at the ball! Ball!”). The objects then remained in silence on the monitor, such that the total trial length was 9.5 seconds. After the test phase was completed, the unlabeled object disappeared, while the labeled object (or the novel object in the case of novel label trials) moved around on the monitor for 2 seconds with accompanying music. Previous studies of word comprehension have suggested that such visual feedback keeps infants on-task in preferential looking studies (Killing & Bishop, 2008). The results of the current and past studies have found no evidence that this reinforcement drives infants’ performance on novel label trials (see Results; Halberda, 2003).

Infants were presented with 24 test trials, in four blocks of six trials per block, in an experimental design similar to that used by Halberda (2003). The first and third blocks

\textsuperscript{10} See Appendix 4 for University of British Columbia Research Ethics Board approval certificate for the studies reported in this paper.
consisted of known vs. known trials (ball-car), while the second and fourth blocks consisted of known vs. novel trials (shoe-nil). Each object was labeled on half of the trials in which it appeared, thus a total of six times. Each infant saw the objects in a consistent configuration throughout all the trials (e.g., ball on left, car on right). Eight stimulus orders were created to counterbalance side and order of presentation across infants. A bright circular pattern was presented in the center of the monitor between trials, to ensure that trials began with a central visual fixation. The total duration of the study was approximately 7 minutes.

Infant eye-gaze data were collected at 20 ms intervals by the eye tracker, and each time interval was classified as a look towards the left side object, a look towards the right side object, or no look towards either object. Data were equated to the onset of each label for each trial, so that they could be collapsed across trial type in order to measure the infant’s success at orienting to the labeled object.

4.2.2 Results and discussion.

Infants’ responses to familiar and novel words were examined in a window that began 360 and ended 2000 ms after the onset of the target word. A number of other studies investigating word comprehension in infants and adults have used a similar initial time point as a plausible minimum time required to respond to a word, due to the time needed both to process the word and to initiate an eye movement (e.g., Dahan, Swingley, Tanenhaus, & Magnuson, 2000). Looking time after 2000 ms post-word-onset is less likely to be in response to the word itself (Fernald, Perfors, & Marchman, 2006; Swingley & Fernald, 2002). Only trials with sufficient attention during the first two seconds post-word-onset, i.e., those with more than 750 ms of looking to the two objects, were included. Seventeen percent of all trials were excluded due to insufficient attention.

An individual baseline score was calculated for each infant, as the proportion of time the infant looked at a particular object during the 3 second silent baseline period on all
trials in which that object was onscreen. Trials during which the infant looked less than 1 out of the 3 seconds were excluded from the calculation. A 2 (object type: familiar, novel) x 3 (language background: monolingual, bilingual, trilingual) ANOVA showed that infants had an overall preference for looking at the familiar objects during baseline over the novel object, $F(1,45)=24.43, p<.0005$, but this did not interact with language background, $F(2,45)=.204, p=.816$. This replicates previous findings that infants prefer to look at objects with known names over other objects (Schafer, Plunkett, & Harris, 1999; White & Morgan, 2008). Thus, to control for inherent baseline preferences, all subsequent analyses were conducted with difference scores, which subtracted each individual’s baseline preference from the proportion of time they looked at the target object after labeling. A positive difference score therefore indicates increased looking at the target object after labeling.

Familiar label trials were analyzed first, to assess whether infants understood the task. Success would be shown by an increase in looking at the target object. One-tailed t-tests on infants’ familiar label difference scores confirmed that monolinguals, $M=.12, SD=.079, t(15)=5.97, p<.005, d=1.49$, bilinguals, $M=.066, SD=.13, t(15)=1.96, p=.035, d=.49$, and trilinguals $M=.14, SD=.243, t(15)=2.46, p=.014, d=.61$ all increased looking to the target object upon hearing its label. A one-way ANOVA confirmed no significant differences among language exposure groups $F(2,45)=1.01, p=.37$.

To examine infants’ ability to disambiguate the novel noun by increasing their attention to the novel object, one-tailed t-tests were performed on infants’ difference scores for novel label trials (see Figure 4.2). Monolinguals showed a strong disambiguation effect, significantly increasing attention to the novel object upon hearing a novel label, $M=.12, SD=.18, t(15)=2.63, p=.0095, d=.66$. Increased attention to the novel object was seen on the first 5 of the 6 experimental trials. Bilinguals showed a similar but marginal pattern, $M=.08, SD=.19, t(15)=1.69, p=.057, d=.42$. Bilinguals’ average difference score was positive on all 6
experimental trials. Trilinguals showed no increase in looking towards the novel object upon hearing the novel label, $M=-.033, SD=.24, t(15)=-.563, \text{ns.}^{11}$ Their average difference score was positive on 3 and negative on 3 trials. To assess whether infants’ performance improved across trials due to the feedback provided after each trial (when the target object moved on the screen to music), a linear trend analysis was performed separately for each group. This analysis showed that infants’ performance did not improve over successive trials, as there was no significant linear trend for monolinguals, $F(1)=1.86, p=.25$, bilinguals, $F(1)=.081, p=.802$, or trilinguals, $F(1)=.404, p=.55$. Results for both familiar label and novel label trials are presented in Figure 4.2.

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11 To ensure that this pattern of results was not an artifact of the 360-2000ms window of analysis, additional analyses were conducted on the 2000-4000ms time window. Results were almost identical to those found in the earlier window. One-tailed t-tests showed that monolinguals showed strong disambiguation, $M=.13, t(15)=2.69, p=.009, d=.67$, bilinguals showed marginal use of disambiguation, $M=.11, t(15)=1.72, p=.057, d=.43$, and trilinguals showed no evidence of using disambiguation, $M=.04, t(13)=.76, p=.23, d=.20$. The trilingual results here are based on 14 infants as 2 of the participating infants lost interest during the later part of each trial.
A linear regression analysis was performed to investigate what aspects of infants’ language proficiency and experience predicted performance on novel label trials. The use of linear regression preserves the inherent ordering of the groups in terms of the number of languages infants are learning (monolingual < bilingual < trilingual), a feature of our experimental design which cannot be modeled by techniques such as ANOVA or ANCOVA. The number of languages being learned by the infant was a significant predictor of infants’ difference scores, $\beta=-.317$, $t(44)=-2.02$, $p=.05$, while English MCDI comprehension, $\beta=-.008$, $t(44)=-.04$, $p=.97$ and production scores $\beta=-.048$, $t(44)=.26$, $p=.80$ showed almost no association with performance.
4.3 Study 2

4.3.1 Method.

To rule out the possibility that any incidental aspects of the procedure drove infants’ responses, Study 2 was run as a control study. The procedure was identical to that of Study 1, except that object label phrases (e.g., “Look at the ball! Ball!”) were replaced with no-label attention phrases. Three attention phrases were used: “Look at that! Look!” “Can you see it? Wow!” and “There it is! Look!”. Visual stimuli were unchanged. That is, on each trial, one object of the pair moved on the screen accompanied by music as it did in Study 1, however the particular object that moved was unrelated to the attention phrase.

Sixteen infants (half female) participated. Nine of the participants were from monolingual English-speaking families, and seven were from bilingual families. Data from an additional 9 infants were excluded due to disinterest in the procedure (4), crying (2), restlessness (2), and equipment failure (1). Bilinguals’ exposure to their languages was assessed as in Study 1, and bilingual infants were reported to hear English an average of 49% of the time (range: 28 to 68%) and their other language an average of 50% (range: 28 to 72%) of the time. One bilingual infant was hearing a small amount (8%) of a third language. Because of experimenter error, CDIs were only collected for half of the infants: 5 monolinguals and 3 bilinguals. These infants had an average receptive vocabulary of 261 ($SD=98$; range: 153-452) and productive vocabulary of 77 ($SD=77$; range: 19-190), making their vocabulary sizes comparable to those of monolinguals in Study 1.

4.3.2 Results and discussion.

Infants’ difference scores were analyzed as in Study 1. One-tailed t-tests showed that infants did not significantly increase looking to the target object on familiar label trials, $M=.07$, $SD=.14$, $t(15)=.45$, $p=.33$, $d=.5$. On novel label trials, infants showed a small decrease
in attention to the novel object after hearing the no-label attention phrase, $M=.082, SD=.19$, $t(15)=-1.59$, ns. Infants’ failure to engage in systematic looking behavior confirms that incidental aspects of the experimental procedure cannot account for their performance in Study 1, and replicates, with an older age group, a similar study conducted by Halberda (2003).

4.4 General discussion

The current research sought to determine whether early language experience influences the development of a word-learning heuristic: the disambiguation of novel nouns by associating them with novel referents. We tested three groups of infants aged 17-18 months who were growing up learning different numbers of languages: monolinguals, bilinguals, and trilinguals. Monolinguals showed disambiguation strongly (replicating Halberda, 2003, who tested English-learners at a similar age), bilinguals showed marginal use of disambiguation, and trilinguals showed no disambiguation. Incidental aspects of the experimental procedure did not drive the result, as those infants that showed disambiguation did so from the very first trial, and infants responded randomly in a control study in which a no-label attention phrase was used rather than a novel label. Further, the results cannot be explained by generalized differences in performance in a preferential looking task, as all three groups succeeded on familiar label trials, while differing only on novel label trials. Our results clearly demonstrate that early language experience influences the development of disambiguation (see Houston-Price, Caloghiris, & Raviglione, 2010, for a recent extension).

Established accounts of disambiguation can be distinguished by their predictions concerning the role of language experience in infants’ development of this heuristic. The mutual exclusivity account is agnostic, stating that the developmental origins remain unknown. Socio-pragmatic accounts suggest that social understanding, rather than language
experience, should underlie developmental differences in disambiguation across infants. Existing research to date comparing socio-pragmatic development in monolinguals and bilinguals has mostly investigated theory of mind development, and has shown that bilingual children outperform monolinguals in theory of mind tasks (Goetz, 2003; Kovács, 2009). While there is disagreement about whether this advantage stems from social (Goetz, 2003) or cognitive (Kovács, 2009) bases, the existing research predicts that if anything, multilingual children should be superior to monolingual children in social understanding. Under socio-pragmatic accounts, this would imply a precocious ability to disambiguate novel nouns, a pattern opposite to our results.

Could the N3C account explain our results? The N3C account proposes that children are only able to disambiguate novel nouns once they acquire enough words to have the insight that all objects have a name (Mervis & Bertrand, 1994). In the current study, our three language exposure groups did differ with respect to English vocabulary size, but did not account for our results. A regression analysis revealed that neither English production nor English comprehension vocabulary size predicted performance on novel label trials. Further, if English vocabulary size drives the development of infants’ ability to disambiguate novel English words, then trilinguals should have outperformed bilinguals as they had larger vocabularies, but this was not the case.

Considering only English vocabulary size underestimates bilingual and trilingual infants’ lexical knowledge because these infants also know words in their non-English languages (De Houwer, Bornstein, & De Coster, 2006; Pearson, Fernández, & Oller, 1993). Due to the numerous different languages represented in the current study, non-English vocabularies could not be measured. Could the use of disambiguation be tied to total vocabulary size across all languages, rather than English vocabulary size? Several studies of bilingual infants and toddlers have suggested that bilinguals know the same or more words
than their monolingual peers when both languages are taken into account (Junker & Stockman, 2002; Pearson et al., 1993). In the current study, exposure to various languages was fairly balanced amongst the multilingual groups. Assuming that these infants knew on average the same number of other-language words as they did English-language words, their total vocabulary size would have been even larger than that of the monolingual group, which would yield precocious disambiguation by the multilinguals, and not the decreased use of disambiguation that we found. Although lack of data on infants’ non-English vocabularies means that this possibility cannot be totally ruled out, vocabulary size across languages is unlikely to account for the results of the current study.

How then might experience in a multilingual environment influence the development of disambiguation? Our results showed that the degree to which infants showed disambiguation co-varied with the number of languages they were learning: the more languages being learned, the less the infants showed disambiguation. We suggest that the development of disambiguation is influenced by the structure rather than the size of the vocabulary. As they learn their two languages, bilingual children often acquire cross-language synonyms or translation equivalents (De Houwer et al., 2006; Junker & Stockman, 2002; Pearson et al., 1993; Pearson, Fernández, & Oller, 1995). Translation equivalents represent a departure from the one-to-one mapping between word and concept that is typical of monolingual vocabularies. Trilinguals might know even more translation equivalents than bilinguals. Language experience could influence early disambiguation because knowledge of many-to-one mappings delays its development in the multilingual, because knowledge of one-to-one mappings promotes its development in the monolingual, or through an interplay of both factors.

In the past, researchers have reasoned about how word-learning biases may influence the early lexicon, by suggesting that bilinguals’ knowledge of translation
equivalents can be seen as evidence against one-to-one mapping biases such as mutual exclusivity and therefore in favor of other biases such as N3C (Golinkoff, Mervis, & Hirsh-Pasek, 1994, p.144). This argument sees word-learning biases and related heuristics such as disambiguation as coming online before early lexical knowledge is acquired. However, our results suggest the reverse, that lexical knowledge, in particular the knowledge of translation equivalents, precede and ultimately influence the development of disambiguation. This "lexicon structure hypothesis" could be tested and refined empirically by studies of monolingual and multilingual infants that relate their use of disambiguation to the number of one-to-one versus many-to-one mappings that their lexicons contain.

Recent computational accounts of disambiguation can also be invoked to consider how differences in disambiguation between monolinguals and multilinguals might arise due to the structure and content of their respective lexicons. These accounts posit that when listeners hear a novel word, an activation fraction is computed for each candidate referent, in our case a novel object and a familiar object (Merriman, 1999; Regier, 2003). The activation fraction is computed by summing the activation the candidate referent receives from the novel word (forming the numerator) and dividing by the activation that a candidate object receives from all words in the lexicon (the denominator). The numerator of the activation fraction is similar for both the familiar and novel objects, as it is mostly a function of noise in the system. The denominator is larger for the familiar object than for the novel object because the familiar object is activated by many words in the lexicon, while the novel object is not. Because they have similar numerators but the novel object has a smaller denominator, the activation fraction of the novel object is larger than that of the familiar object. This makes it more likely that the novel word will become associated with the novel object.
For multilinguals, known words from both languages may contribute to the denominator of the activation fraction, as a number of studies have shown that words from both the task language and other languages are active when bilingual adults perform auditory comprehension tasks (Blumenfeld & Marian, 2007; Spivey & Marian, 1999). Similarly, if words in multiple languages are activated for infants performing disambiguation tasks, multilinguals’ activation ratio for the familiar object in response to the novel word would be even smaller than monolinguals', as words from multiple languages are associated with the familiar object. All else being equal, then, multilinguals would show even stronger disambiguation than bilinguals do, which is opposite to the pattern we found. Admittedly, computational accounts of disambiguation have thus far not explicitly addressed the multilingual situation, and further it is likely that all else is not equal between monolingual and multilinguals in tasks such as disambiguation. Nevertheless our evidence is incompatible with current computational accounts of disambiguation. An expansion of computational accounts that reflects how multilinguals process, represent, and negotiate among their languages, and the role that translation equivalents might play, seems warranted.

How multilingual infants negotiate among their languages has other implications for a full understanding of disambiguation. Our study presented infants with a novel English noun in the context of a novel object and a shoe, a highly familiar object for which infants likely knew a word in each of their languages. However, multilingual infants may sometimes encounter a novel noun in the context of a novel object and a familiar object that they can only name in one of their languages. From a word-learning perspective, the interpretation of the novel noun should depend on whether the task language (the language in which the novel noun is embedded), matches the language in which the infant can name the familiar object. When that known word is in the same language as the task (e.g. the infant knows the
English word “shoe”, and a novel word is presented in an English carrier phrase) looking at the novel object in response to the novel word is a case of within-language disambiguation. Like disambiguation in monolinguals, within-language disambiguation allows bilinguals to avoid unlikely referents for new words, as it is unlikely that “shoe” has two English labels. However, if that known word is in the other language (e.g., the infant knows the French word “chaussure”, and the novel word is presented in an English carrier phrase), then looking at the novel object in response to a novel noun would be a case of between-language disambiguation. Between-language disambiguation might interfere with making correct word-object associations, as a children might avoid a correct referent for an object simply because they already know a word for the object in another language. Two and 3-year-old bilinguals sometimes show this non-adaptive, between-language disambiguation (Frank & Poulin-Dubois, 2002), while older bilinguals are more likely to understand that objects may have different names in different languages (Au & Glusman, 1990).

Critically, the ability of bilinguals to apply disambiguation only in a within-language context, and to avoid applying it between languages, rests on their ability to differentiate their two languages. Thus far, there has been little consensus as to when bilinguals understand that different words are part of different languages, and even less is known about when they are able to apply such knowledge in the service of word learning (for a review, see Paradis, 2001). Further studies of disambiguation in bilinguals might simultaneously be able to inform the debate on language differentiation in bilinguals, and further illuminate our understanding of word learning heuristics. To the extent that bilingual infants differ in within-language versus between-language disambiguation, this implies that (a) bilinguals differentiate words as belonging to two languages and (b) disambiguation stems from the knowledge of an appropriate noun for the familiar object rather than the novelty of the novel object.
The developmental origins of word-learning biases remain largely unexplored. The current work significantly advances our understanding of these biases by showing that different types of early language experience influence the emergence of one elemental word-learning heuristic. More broadly, these results point to the utility of systematic investigations of different forms of early language experience as a means for better understanding fundamental mechanisms in language acquisition.
4.5 References


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5 Knowledge of translation equivalents influences how bilingual infants learn words\textsuperscript{12}

5.1 Introduction

Children must be efficient word learners to acquire the thousands of words that they will eventually know in adulthood. It is well-established that children and infants have many word learning tools at their disposal, from associative mechanisms (Smith & Yu, 2008; Werker, Cohen, Lloyd, Casasola, & Stager, 1998), to an understanding of the referential nature of words (Waxman & Gelman, 2009). A particular obstacle that children must overcome in learning new words is the problem of induction: given the many possible meanings of a new word, how do children know what the “right” meaning is? Fortunately, children do not consider just any meaning when they hear a new word, but rather systematically prefer some meanings over others. For example, children expect new words to refer to whole objects rather than to their parts (Golinkoff, Mervis, & Hirsh-Pasek, 1994; Markman, 1989), and expect that nouns extend to other objects of the same kind or shape (Landau, Smith, & Jones, 1988; Markman & Hutchinson, 1988; Soja, Carey, & Spelke, 1991).

Children also show systematicity in how they interpret a novel label when it is uttered in the presence of a familiar already-nameable object and another object without a known name. Children tend to assume that the novel label goes with the novel object, rather than with the one that already has a name, a heuristic known as disambiguation (Merriman & Bowman, 1989). For example, imagine a young child sitting at a kitchen table, where there is a cup (for which the child knows the label \textit{cup}) and a spatula (an object with which the child is unfamiliar). Upon the request, “Give me the \textit{spatula}”, children tend to assume that \textit{spatula} refers to the long-handled utensil, rather than the round drinking vessel. Numerous

\textsuperscript{12} A version of this chapter will be submitted for publication. Byers-Heinlein, K., & Werker, J.F. (in preparation). \textit{Knowledge of translation equivalents influences how bilinguals learn words.}
explanations have been advanced to explain what underlies children’s tendency to disambiguate novel nouns in this way. Markman and colleagues have proposed that children operate under an assumption that object labels are mutually exclusive, and thus avoid giving an object a second name (Markman & Wachtel, 1988). Another proposal is the Novel-Name-Nameless Category principle (N3C; Golinkoff et al., 1994; Mervis & Bertrand, 1994), and the related lexical-gap filling hypothesis (Merriman & Bowman, 1989), which suggest that children are motivated to find a name for each object. Socio-pragmatic explanations such as the principle of contrast (Clark, 1990) and the pragmatic account (Diesendruck & Markson, 2001), posit that children’s behavior is based on their reasoning about others’ underlying intentions, e.g. “If she had wanted the cup she would have said cup, but she said spatula so she must have wanted the other one.”

Although each of these accounts differs significantly from a theoretical perspective, they frequently overlap on the predictions that they generate for children’s behavior. Some experiments have attempted to disentangle the various accounts (e.g. Diesendruck & Markson, 2001; Jaswal & Hansen, 2006; Markman, Wasow, & Hansen, 2003; Mervis, Golinkoff, & Bertrand, 1994) but no general consensus has been reached. One way to surmount these obstacles is to reframe the research questions that motivate empirical work on disambiguation.

Here, we build on a growing developmental approach, which aims to better understand disambiguation by studying children across different ages and from different language backgrounds (e.g. Byers-Heinlein & Werker, 2009; Halberda, 2003; Houston-Price, Caloghiris, & Raviglione, 2010). These studies begin to address three important questions engendered by a developmental perspective on understanding disambiguation: 1) what is the developmental time course of disambiguation, 2) does experience play a role in the development of disambiguation, and 3) if so what type of experience is necessary for
disambiguation to develop? This paper will first review research addressing each of these questions in turn. We then describe the current study, which addresses the role of experience in the development of disambiguation. We test the hypothesis that it is the one-to-one mapping structure between words and concepts in children’s emerging lexicons that enables them to develop a disambiguation word learning heuristic. Our study asks whether the structure of bilingual infants’ lexicons, operationalized as the percentage of translation equivalents (cross-language synonyms) in their vocabularies, predicts whether they have developed the ability to disambiguate novel words at 17-18 months-of-age.

5.1.1 The development of disambiguation.

Disambiguation, while shown by children across a wide range of ages, is not available when word learning first begins late in the first year of life (Fenson, Marchman, Thal, Dale, & Bates, 2007; Tincoff & Jusczyk, 1999; although see Dewar & Xu, 2007, for evidence that 9-month-olds expect distinct words to refer to distinct kinds). Halberda (2003) used a preferential looking paradigm to study disambiguation in infants who ranged in age from 14 to 17 months, to explore age-related changes in disambiguation. On disambiguation trials, infants were shown a familiar and an unfamiliar object (e.g. a car and a phototube) on two side by side monitors, and asked to “Look at the dax”. Seventeen-month-olds showed evidence of disambiguating the novel noun dax by increasing their attention to the novel object. Sixteen month-old-infants were at chance. However, 14-month-old infants increased their attention to the familiar object. Halberda interpreted these results as indicative of a process-of-elimination word-learning strategy called disjunctive syllogism (A or B, not A, therefore B), that underlies infants’ disambiguation of novel words. In this case, the infant disambiguates the referent of the novel word dax by implicitly reasoning, “Dax must refer to either the car or the phototube. It’s not the car, therefore it must be the phototube.” To complete the disjunctive syllogism, infants must
first rule out the car as a potential referent of dax. Halberda argued that only the oldest group of infants was able to complete the disjunctive syllogism, while younger infants got stuck on the first step (the dax is not the car) thereby increasing their attention to the familiar object rather than to the novel one. Further evidence for disjunctive syllogism as the computational structure underlying disambiguation has been demonstrated in eye tracking studies with preschoolers and adults (Halberda, 2006; see also Mather & Plunkett, 2009 for further evidence from infants).

5.1.2 The role of experience in the development of disambiguation.

Cross-language studies provide an ideal way to address the question of whether the documented age-related changes in disambiguation are related to maturation or to experience. If disambiguation develops in the same time frame regardless of early language experience, this would be evidence of maturation-based development. Conversely, if infants from different language backgrounds show different patterns in the development of disambiguation, then this would provide evidence for a role of early language experience.

Several studies have compared disambiguation in infants growing up monolingual to infants growing up bi- and multilingual. Monolinguals can disambiguate a novel word as early as 16-18 months (Byers-Heinlein & Werker, 2009; Halberda, 2003; Markman et al., 2003), and continue to show disambiguation in studies that have tested infants a few months older (Houston-Price et al., 2010; White & Morgan, 2008). Research to date that has looked at bilingual and multilingual infants at these same ages has failed to find strong evidence for disambiguation. Byers-Heinlein and Werker (2009) found that 17-18 month-old bilinguals showed only marginal evidence of disambiguating a novel word, while trilinguals showed no evidence of using disambiguation. A regression analysis across the monolingual, bilingual, and trilingual groups showed that the number of languages being learned by the infants predicted the degree to which they showed disambiguation: the more
languages being learned, the less disambiguation was shown. Houston-Price and colleagues similarly found no evidence of disambiguation in 17-22 month-old bilinguals (Houston-Price et al., 2010). Evidence of less robust use of disambiguation in bilinguals has also been shown with preschool and school-aged children (e.g. Davidson, Jergovic, Imami, & Theodos, 1997; Diesendruck, 2005; Merriman & Kutlesic, 1993; but see also Frank & Poulin-Dubois, 2002; Merriman & Kutlesic, 1993). By testing monolinguals and multilinguals of the same age using identical procedures, the studies of Byers-Heinlein & Werker (2009) and Houston-Price and colleagues (2010) provide strong evidence that early language experience influences the development of disambiguation.

5.1.3 One-to-one mapping and the impact of translation equivalents.

The question still remains as to why monolingual but not bilingual experience supports the development of disambiguation by 17-18 months. Monolingual infants typically encounter one basic level label for each object, and it has been hypothesized this experience could lead to word learning principles including those underlying disambiguation (Golinkoff et al., 1994; Mervis & Bertrand, 1994). Indeed, there is some evidence that for monolingual children, disambiguation develops with growing vocabulary knowledge, perhaps due to mounting evidence for one-to-one mapping between words and the concepts they label. Mervis and Bertrand (1994) tested 16-20 month-old infants in a task that did not require disambiguation per se, but rather a related skill – fast mapping of a novel label to a novel object given direct labeling evidence. Mervis and Bertrand reported that only the infants with the largest productive vocabularies were able to succeed in the fast mapping task, and concluded that disambiguation develops when infants have the insight that each object should have a name. Clearer evidence for a link between lexical knowledge and disambiguation comes from a group of 17-22 month-old English-learning infants tested in a preferential looking paradigm. Infants’ tendency to disambiguate a novel
label was significantly correlated with their receptive vocabulary size ($r = .33$; Houston-Price et al., 2010).

Unlike monolinguals, bilinguals do not experience predominantly one-to-one mappings, rather they typically encounter two basic-level labels for each object, one in each language. Bilinguals’ knowledge of two labels for the same referent could thus fail to promote the emergence of disambiguation (Byers-Heinlein & Werker, 2009; Davidson & Tell, 2005; Frank & Poulin-Dubois, 2002; Houston-Price et al., 2010). In their N3C account, Mervis and Bertrand (1994) put forward the notion that disambiguation develops in monolingual infants as they learn new words, because children have the insight that each object has a name. Under N3C, children’s experience teaches them that objects tend to have names, and thus when they encounter a “nameless category” as exemplified by a novel object they seek out a “novel name” for this object. The N3C account thus predicts that just like monolinguals, bilinguals should develop disambiguation as their vocabularies grow, because encountering multiple labels for each object does not negate the notion that objects should have names. This prediction has thus far not been supported by studies of young bilinguals, which have shown that even given similar vocabulary sizes in the language of testing, bilinguals and monolinguals do not develop disambiguation at the same age (Houston-Price et al., 2010).

To provide a unified account of the early development of disambiguation in both monolinguals and bilinguals, Byers-Heinlein and Werker (2009) put forward the “lexicon structure hypothesis”. The lexicon structure hypothesis posits that an infant (monolingual or multilingual) will use disambiguation when their lexicon supports a notion of one-to-one mapping between a label and the concept it names. The degree of conformity to, or violation of, one-to-one mappings in the lexicon can be measured by determining the number of translation equivalents in a bilingual infant’s lexicon. Translation equivalents are pairs of
words in the bilingual lexicon that are cross-language synonyms. Each translation equivalent pair that a bilingual knows could provide evidence that is contrary to one-to-one mapping between words and concepts.

There have been at least three large-scale studies to date which have attempted to quantify the number of translation equivalents known by bilingual infants. Two studies used the MacArthur-Bates communicative development inventories (CDIs; Fenson et al., 2007). The CDIs measure children’s vocabularies through parental checklists, and have been adapted for use in a number of different languages. Pearson and colleagues examined children’s production of translation equivalents (Pearson, Fernández, & Oller, 1995). In a study of Spanish-English bilinguals aged between 8 and 30 months-old, children knew a translation equivalent for about 30% of the words in their vocabularies. Children’s comprehension of translation equivalents, rather than their production, was examined by De Houwer and colleagues in a study of 13-month-old French-Dutch bilinguals (De Houwer, Bornstein, & De Coster, 2006). On average, infants knew translation equivalents for a mean of 18% of the words in their comprehension vocabularies, with a wide range from less than 1% to 62%. Children who had the largest vocabularies tended to know the most translation equivalents as a percentage of their total vocabulary size. In a study using the Peabody Picture Vocabulary Test with a large sample of English-Spanish bilingual first-graders, children could understand approximately 65% of words in both of their languages (Umbel, Pearson, Fernández, & Oller, 1992), again suggesting that knowledge of translation equivalents grows as children learn more words and “fill in” missing words.

Two findings have been established: disambiguation develops later in bilinguals than in monolinguals, and bilinguals know translation equivalents from early in life. However, these two observations are insufficient to test the causal hypothesis that bilinguals’ knowledge of translation equivalents influences their development of
disambiguation. It could be that some other aspect of bilingualism causes bilinguals to
develop disambiguation later than monolinguals do. For example, it is theoretically possible
that a critical mass of words in a single language is necessary for the emergence of
disambiguation in that language (although see Houston-Price et al., 2010, for data
inconsistent with this possibility). Bilinguals may know fewer words from each individual
language than a same-aged monolingual because their vocabularies are divided between
two languages.

To test the lexicon structure hypothesis, and rule out other potential explanations, it
is necessary to directly assess whether knowledge of translation equivalent affects the
development of disambiguation in bilingual infants. Compelling evidence would be provided
if individual children’s knowledge of translation equivalents predicts whether they use
disambiguation. A negative relationship is expected: those children whose vocabularies are
characterized by the most translation equivalents should show the least use of
disambiguation.

Two studies to date have investigated the relationship between disambiguation and
translation equivalents, but while results were suggestive, they did not allow for strong
conclusions to be drawn. In their study of disambiguation in 17-22 month-old bilinguals,
Houston-Price and colleagues (2010) collected data on the infants’ comprehension
vocabularies in each language. Because children were all learning English plus another
language which varied across the sample, parents filled out a short form of the Oxford
Communicative Inventory for British English (Hamilton, Plunkett, & Schafer, 2000), with
columns to indicate the infant’s understanding of the word in English and in their other
language. On average, infants knew 84 pairs of words that were understood in both of their
languages, or about 38% of their total receptive vocabulary size based on their English and
other language vocabularies as reported in the paper. The correlation between the number
of translation equivalents they knew and their disambiguation performance was in the predicted direction ($r(19) = -0.29$), but this did not reach statistical significance given their sample size ($p = 0.23$). Non-significant trends were found between infants’ disambiguation performance and their non-English vocabulary size ($r = -0.40, p = 0.09$), as well as with their total vocabulary size ($r = -0.37, p = 0.12$). The authors did not examine whether knowledge of translation equivalents as a percentage of vocabulary size correlated with performance.

The second study that investigated the relationship between knowledge of translation equivalents and word learning was done by Frank and Poulin-Dubois (2002). They tested 27- and 35-month-old French-English bilinguals, and children who were monolingual in these languages, on their willingness to learn two labels for the same object. Under the mutual exclusivity framework (Markman & Wachtel, 1988), children assume that each object should only have one name. Adherence to mutual exclusivity can be tested in multiple ways, including both the disambiguation of a novel label by associating it with a novel object, and by testing whether children avoid mapping two labels to the same object when no novel object is present. Frank & Poulin-Dubois tested this second consequence of the mutual exclusivity assumption. They found that both monolinguals and bilinguals avoided mapping two labels to the same object, and the effect was stronger for older children than for younger children. The authors also related performance to bilinguals’ knowledge of translation equivalents. The 27-month old bilinguals knew an average of 47% translation equivalents (range 9-79%), and the 35-month-olds knew an average of 51% translation equivalents (range: 1-95%). Those children who knew the greatest proportion of translation equivalents were the most likely to map two labels onto the same object, thereby violating mutual exclusivity. Correlations between % translation equivalents and adherence to mutual exclusivity (# of trials on which behavior was consistent with mutual exclusivity) were -0.27 for 27-month-olds, and -0.20 for 35-month-olds. Again, although they
were in the predicted direction, these correlations were not statistically significant given the sample sizes ($N_{\text{younger}}=26$, $N_{\text{older}}=28$). The fact that no behavioral difference was seen between monolingual and bilinguals’ word learning could have made it less likely to observe an influence of translation equivalents.

5.1.4 Overview of the current study.

To summarize, disambiguation is a word learning heuristic whereby infants tend to associate a novel word with a novel object rather than with a familiar one. It has long been hypothesized that monolinguals and bilinguals differ in their use of disambiguation because of bilinguals’ knowledge of translation equivalents, words from different languages which name the same referent. The lexicon structure hypothesis posits that disambiguation develops with mounting evidence for one-to-one mapping between words and their referents, and predicts that knowledge of translation equivalents will therefore impede the development of disambiguation in bilingual infants. Thus far, two studies have found the predicted negative relationship between knowledge of translation equivalents and use of disambiguation or a related word-learning behavior, but in neither study was the relationship statistically significant. The current study was designed to provide a more sensitive test of whether knowledge of translation equivalents influences early word learning, specifically infants’ use of disambiguation. If translation equivalents influence the development of disambiguation, then knowledge of translation equivalents might have the greatest impact in bilinguals around the age when disambiguation first emerges in monolinguals.

We tested disambiguation in English-Chinese bilingual infants, between 17 and 18 months-of-age, and used the English and Chinese versions of the CDI to quantify the translation equivalents that they knew. Although previous research has shown that, as a group, bilinguals do not show disambiguation in this paradigm at this age (Byers-Heinlein &
Werker, 2009; Houston-Price et al., 2010), there is significant variability in their performance. The current study examined whether bilinguals’ knowledge of translation equivalents can explain this variation. There are two ways in which one might quantify the degree of overlap in bilinguals’ vocabularies. One approach is to simply count the number of translation equivalents known by bilinguals. A second approach is to consider the proportion of the total vocabulary that these translation equivalents represent. We reasoned that a proportion measure would be the most sensitive, as this would normalize the number of translation equivalents according to infants’ total vocabulary size, thus giving a better characterization of the structure of their lexicons. It was predicted that those children whose vocabularies contained the smallest proportion of translation equivalents would show the strongest use of disambiguation, while those whose vocabularies contained a larger proportion of translation equivalents would show the weakest use of disambiguation.

To rule out the possibility that translation equivalents affect children’s general performance in a two-choice recognition task, rather than just their disambiguation of novel words, we tested infants in a control task of familiar word recognition. It was expected that knowledge of the task language (English) would predict infants’ performance on the familiar word recognition trials, but that their familiar word recognition would be unrelated to their knowledge of translation equivalents.

5.2 Methods

5.2.1 Participants.

A total of 20 (12 female) bilingual infants learning English and Chinese (either Cantonese or Mandarin) were included in the study, with a mean age of 17m27d (range: 17m17d to 18m12d). Nine additional infants were tested but excluded from the analyses.
because the infant was too restless or inattentive to complete the study (4), the infant had a major health concern (2), or because the infant was not reported to understand any of the familiar English words used in the study (2).

5.2.1.1 Language background.

Infants came from homes where English and Chinese had been spoken regularly since the infant was born. Fifteen bilinguals were hearing English and Cantonese, and 5 were hearing English and Mandarin. Most (but not all) parents were ethnically Chinese, and typically one or both parents was Canadian-born or had been raised in Canada and had completed the majority of his/her education in English. The Language Exposure Questionnaire was used to assess bilinguals infants’ exposure to each language (Bosch & Sebastián-Gallés, 1997). On average, infants heard English 49% of the time (range: 27% to 75%) and Chinese 49% of the time (range: 25% to 73%). The percentages do not add up to 100 as one infant was hearing a small amount of a third language (7%).

5.2.2 Materials.

5.2.2.1 Vocabulary measure.

Estimates of infants’ English vocabulary size were obtained by asking parents to complete the Words and Gestures form of the MacArthur-Bates Communicative Development Inventory (CDI; Fenson et al., 2007) which has shown high validity in at least one bilingual sample (Marchman & Martinez-Sussman, 2002). Estimates of infants’ Chinese vocabularies were obtained via the equivalent Mandarin or Cantonese version (as appropriate) of the CDI (Tardif & Fletcher, 2008). The total number of items across the forms was similar: 396 English, 410 Mandarin, and 388 Cantonese. The use of the Words and Gestures form allowed measurement of both infants’ word comprehension and their word production. Where possible, the parent who was most familiar with the child’s
vocabulary in a particular language completed the form. In 4 cases, the parents failed to return complete CDI forms for one or both languages. These infants were included in analyses of the groups’ performance on the behavioral task, but not included in descriptive analyses of vocabulary data, or in analyses assessing the relationship between vocabulary measures and performance on the behavioral tasks.

A trilingual research assistant who was a native Cantonese-Mandarin bilingual and had moved to an English-speaking country in childhood, identified word pairs in the English and Chinese CDIs that were translation equivalents (e.g. English *dog* and Mandarin *gǒu/*Cantonese *gáu*). She verified all English-Cantonese pairings with an English-Cantonese bilingual, and all English-Mandarin pairings with an English-Mandarin bilingual. In some cases, English and Chinese lexicalize the same concept differently. For example, whereas English has the single word *brother*, Chinese has separate words *gēge* for older brother and *dìdi* for younger brother. Thus, if the child knew the English word *brother* and the Mandarin words *gēge* and *dìdi*, these three words counted as two pairs because they encode two different concepts. There were 297 English-Cantonese pairs, and 294 English-Mandarin pairs.

Some previous investigations of children's knowledge of translation equivalents have restricted analyses to those words that had a translation equivalent on the other CDI form (De Houwer et al., 2006; Pearson et al., 1995). In these studies, the translation equivalent pairs a child knew were counted, and this was divided by the total number of pairs across the two CDIs. Words on the CDI without a translation equivalent were excluded from the calculation. This method avoids *underestimating* the proportion of children's vocabularies that have translation equivalents. At the same time, this method is more likely to *overestimate* the proportion of children’s vocabulary that has a translation equivalent. As with all adaptations of the CDI, the Mandarin and Cantonese CDIs do not share some English
items that were unlikely to be known in Chinese (e.g. Cheerios) and instead have items that are more culturally and linguistically relevant (e.g. congee). Parents might therefore be more likely to talk about Cheerios when speaking English and congee when speaking Chinese, making it less likely that a child knows the translation equivalent for these words. This means that the words with a translation equivalent on the other form may be those that the child is most likely to know in both languages, while those words without a translation equivalent may be those words that the child is less likely to know in both languages. We thus chose to include all words reported on the CDIs in both languages in calculating the percentage of translation equivalents that each child knew, to avoid overestimations.

5.2.2.2 Experimental stimuli.

Visual stimuli consisted of four brightly-colored objects, three familiar (ball, car, and shoe) and one novel. The novel object was a slightly modified version of a phototube from the TarrLab Object DataBank (1996). The objects were presented on a black background in consistent pairs: car-ball and phototube-shoe. The objects appeared in different colors on different trials to maintain infant interest, and to ensure generalization across different-colored exemplars of the same object category.

Auditory stimuli were recorded by a female native English speaker who spoke in an infant-directed style. The stimuli consisted of three labels that named the familiar objects—ball, car, shoe, and one label that named the novel phototube object – nil. Nil was chosen as the novel label because it is not a possible Mandarin or Cantonese word. Although nil is a real word for English-speaking adults, its infrequent use and abstract meaning make it unlikely that infants are familiar with this word. Each label was recorded in isolation, and with three carrier phrases, “Look at the __”, “Find the __”, and “Where is the __”. For each
trial, the label was presented once embedded in a carrier phrase (chosen quasi-randomly), and again in isolation (e.g., “Look at the ball! Ball!”).

To ensure that infants were likely to know the familiar words used in this study, we examined infants’ reported comprehension on the corresponding CDI items. Most relevant to the study was infants’ understanding of the words in English, the language of testing. Comprehension of ball, car, and shoe ranged from 80-100%. Nearly all infants were reported to also know the Chinese translations of these words, with reported comprehension ranging from 94-100% of infants. Therefore, the vast majority of infants were reported to understand the test words in both English and Chinese.

5.2.2.3 Apparatus.

Data were collected using a Tobii 1750 eye tracking system, which consisted of an LCD monitor for the presentation of visual stimuli with a built-in eye tracking camera. Infrared lights shone from panels surrounding the monitor, and the reflection of this light from the infants’ cornea provided data for precise location of the infant’s gaze. Auditory stimuli were presented via computer speakers located behind a black cardboard panel, on either side of the eye tracker. A PC computer running the Tobii Clearview software program both controlled the stimulus presentation and collected the eye tracking data.

5.2.3 Procedure.

Infants were tested in a dimly-lit, sound-attenuated room.13 The experimenter controlled the study from a computer and a closed-circuit TV monitor, located in a screened-off area of the same room. Before commencing the study, the experimenter settled the infant on the parent’s lap, and positioned the eye tracking monitor approximately 60cm away from the infant’s eyes. Parents wore a blindfold or closed their eyes for the duration of

13 See Appendix 4 for University of British Columbia Research Ethics Board approval certificate for the studies reported in this paper.
the study in order to avoid biasing the infant. Once the infant was settled, the experimenter initiated a five-point infant calibration routine. Following calibration, testing began.

At the beginning of testing, each infant saw a warm-up trial during which a spinning waterwheel appeared sequentially on each side of the monitor. Experimental trials began immediately following the warm-up. On each trial, the object pair first appeared in silence on the monitor for 3 seconds, so that infants’ baseline preference for each object could be measured. Immediately following the silent baseline, an auditory stimulus was played that named one of the objects (e.g., “Look at the ball! Ball!”). The objects then remained in silence on the monitor, such that the total trial length was 9.5 seconds. After the test phase was completed, the unlabeled object disappeared, while the labeled object moved around on the monitor for 2 seconds with accompanying music. Previous studies of word comprehension have suggested that such visual feedback keeps infants on-task in preferential looking studies (Killing & Bishop, 2008). The results of past studies using the same paradigm have found no evidence that this reinforcement drives infants’ performance on novel label trials (Byers-Heinlein & Werker, 2009; Halberda, 2003).

Infants were presented with 24 test trials, in four blocks of six trials per block. The first and third blocks consisted of known vs. known trials (ball-car), while the second and fourth blocks consisted of known vs. novel trials (shoe-nil). Each object was labeled on half of the trials in which it appeared, thus a total of six times. Each infant saw the objects in a consistent configuration throughout all the trials (e.g. ball on left, car on right). Eight stimulus orders were created to counterbalance side and order of presentation across infants. A bright circular pattern was presented in the center of the monitor between trials, to ensure that trials began with a central visual fixation. The total duration of the study was approximately 7 minutes.
Infant eye-gaze data were collected at 20 ms intervals by the eye tracker, and each time interval was classified as a look towards the left side object, a look towards the right side object, or failure to look towards either object. Data were equated to the onset of each label for each trial, so that they could be collapsed across trial type in order to measure the infant’s success at orienting to the labeled object.

Following the experimental session, families returned to the reception area while the parents completed the Language Exposure Questionnaire, an English version of the CDI (Fenson et al., 2007), and a Chinese version of the CDI (Tardif & Fletcher, 2008).

5.3 Results

5.3.1 Vocabulary measures.

Infants’ vocabularies were quantified in several ways (see Table 5.1 for detailed descriptive statistics). Parallel values were computed for comprehension vocabulary (words that the child could understand) and production vocabulary (words that the child could say). The total number of words children understood across both their languages averaged 341, and the total number produced averaged 61. However, unlike monolinguals for whom production and comprehension are typically highly correlated (Fenson et al., 2007), the correlation between comprehension and production of words summed across both English and Chinese (total vocabulary size) was not significant, \( r(14) = .24, p = .36 \).

Examining each language separately, there was a significant correlation between English comprehension and production, \( r(14) = .69, p = .003 \), but not between comprehension and production in Chinese, \( r(14) = .10, p = .70 \). Children understood on average 54 \((SD=95)\) more words in Chinese than in English, which was a statistically significant difference \( t(15) = 2.249, p = .04, d = .56 \). Children could produce 10 \((SD=29)\) more words in English than in Chinese, but this difference was not significant, \( t(14) = 1.30, p = .21, d = .33 \).
The total number of translation equivalent pairs was counted in the manner described above. All infants had at least some translation equivalents in their comprehension vocabularies, and all but two had translation equivalents in their productive vocabularies. Children could understand 87 pairs on average, and could produce 9 pairs, but these two measures were not significantly correlated, $r(16)=.21, p=.44$. To quantify the degree to which infants’ vocabularies overlapped, the percentage of infants’ vocabularies that constituted translation equivalents was calculating by taking the total number of words for which the infant knew a translation equivalent, and dividing by the total vocabulary size. On average, 46% of the words that children understood had a translation equivalent, while the same was true for 26% of words in production.

The total conceptual vocabulary was calculated as the number of meanings lexicalized by the child, thus the total vocabulary minus the number of redundant words whose meaning was captured by its translation equivalent. In comprehension, children had lexicalized an average of 260 meanings, and could produce words for a mean of 53 meanings. No significant correlation was found between comprehension and production for children’s total conceptual vocabularies, $r(14)=.27, p=.32$. Pearson and colleagues have suggested that bilinguals’ total conceptual vocabulary (Pearson, Fernández, & Oller, 1993) is the most comparable to monolinguals’ vocabulary size. An examination of lexical norms on the English CDI (Fenson et al., 2007) showed that bilinguals’ average comprehension of concepts in this study was at the 50\textsuperscript{th} percentile reported for 18-month-old monolingual English-learners, and identical to the average comprehension vocabulary of a previous sample of same-aged English monolinguals living in the same community (Byers-Heinlein & Werker, 2009; see Chapter 3). However, bilinguals’ average production was only at the 20\textsuperscript{th} percentile on monolingual English norms, and was on average 23 words smaller than the
monolingual community comparison group reported in a previous paper (Byers-Heinlein & Werker, 2009; Chapter 3).

Table 5.1: Infants’ vocabulary data across a range of measures.

<table>
<thead>
<tr>
<th></th>
<th>Comprehension</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>English vocabulary</td>
<td>144 (76)</td>
<td>26-255</td>
</tr>
<tr>
<td>Chinese vocabulary</td>
<td>198 (71)</td>
<td>67-287</td>
</tr>
<tr>
<td>Total vocabulary</td>
<td>341 (112)</td>
<td>165-496</td>
</tr>
<tr>
<td>Total conceptual</td>
<td>260 (68)</td>
<td>140-351</td>
</tr>
<tr>
<td># translation equivalent</td>
<td>87 (50)</td>
<td>23-165</td>
</tr>
<tr>
<td>% words with a translation</td>
<td>46 (14)</td>
<td>17-66</td>
</tr>
</tbody>
</table>

5.3.2 Behavioral task.

Based on previous work identifying the minimum time needed to process a word and initiate an eye movement (Dahan, Swingley, Tanenhaus, & Magnuson, 2000), as well as the typical length of time that infants sustain fixation after responding to a word (Dahan et al., 2000; Fernald, Perfors, & Marchman, 2006; Swingley, Pinto, & Fernald, 1999), an analysis window of 360-2000ms after the onset of the target word was identified (as in Chapter 4; Byers-Heinlein & Werker, 2009). Infants’ responses to both the familiar words and the novel word were analyzed only in this time window. Trials where infants looked 750ms or less were excluded from the analysis.

An individual baseline score was calculated for each infant, as the proportion of time the infant looked at a particular object during the 3 second silent baseline period on all trials in which that object was onscreen. Trials during which the infant looked less than 1 out of the 3 seconds were excluded from the calculation. Infants tended to show more
interest during baseline to the familiar objects as opposed to the novel object, \( t(19)=3.00, p=.007, d=.67 \). This replicates previous findings that infants prefer to look at objects with known names over other objects (Schafer, Plunkett, & Harris, 1999). Thus, to control for inherent baseline preferences, and as in Byers-Heinlein & Werker (2009; presented in Chapter 4), all subsequent analyses were conducted with difference scores, which subtracted each individual’s baseline preference from the proportion of time they looked at the target object after labeling. A positive difference score therefore indicates increased looking at the target object after labeling.

Familiar label trials were analyzed first. A preliminary between-subjects ANOVA showed that infants’ performance on familiar label trials did not vary as a function of object, \( F(2,38)=1.86, p=.17, \eta^2_p=.089 \), therefore data were collapsed across the three familiar objects. A one-tailed t-test indicated that infants significantly increased their looking towards the familiar target upon hearing its label, \( M=.072, SD=.15, t(19)=2.15, p=.023, d=.48 \). Next, a one-tailed analysis was performed to examine whether, as a group, infants disambiguated the novel noun by orienting to the novel object. As a group, Chinese-English bilinguals did not show disambiguation, \( M=.060, SD=.30, t(19)=.89, p=.19, d=.20 \). Finally, a correlation was computed between infants’ performance on familiar label and novel label trials. No significant correlation was found, \( r(18)=-.25, p=.29 \). High levels of variability amongst responses for both familiar label trials and novel label trials motivated an examination of whether individual differences contributed to the results.

5.3.3 Relation of performance to English vocabulary size.

As the task was in English, it was reasonable to evaluate whether infants’ English vocabulary size affected their performance. It was predicted that those infants with higher English vocabularies would show the best performance on familiar label trials, but that English vocabulary would not affect performance on novel label trials. A median split was
performed based on children’s English comprehension vocabularies. The low-vocabulary group ranged from understanding 26-130 words ($M=83, SD=41$), and the high-vocabulary group ranged from understanding 136-255 words ($M=205, SD=47$).

**5.3.3.1 Familiar label trials.**

The high vocabulary group did marginally better than the low-vocabulary group on familiar label trials, $t(14) = 1.47, p=.08, d=.74$. Independent-samples t-tests confirmed that the high-vocabulary group showed a significant tendency to increase attention to the familiar object upon hearing its label, $M=.10, SD=.14, t(7)=2.13, p=.035, d=.75$. Six out of 8 infants in the high vocabulary group had a positive difference score. However, in the low-vocabulary group there was not a significant increase in attention to the familiar object, $M=-.03, SD=.32, p=.746, d=.02$, two-tailed. Only 4 out of 8 infants in the low-vocabulary group increased their attention to the familiar objects upon hearing their labels. When examined continuously rather than in a dichotomously, a non-significant positive correlation was found between English vocabulary size and performance on familiar label trials, $r(14)=.36, p=.17$.

**5.3.3.2 Novel label trials.**

As predicted, for novel label trials, there was no significant difference in performance between the high-vocabulary and the low-vocabulary groups, $t(14)=1.00, p=.17, d=.50$. Further, no significant correlation was found between infants’ vocabulary size and their performance on novel label trials, $r(14)=-.17, p=.53$.

**5.3.4 Relationship of performance to knowledge of translation equivalents.**

The main hypothesis was that infants’ use of disambiguation would be related to the structure, rather than to the size, of their lexicons. Lexical structure was operationalized as the proportion of words in infants’ vocabularies for which they knew translation
equivalents. It was predicted that infants with the most overlap would show the worst performance, and that this would be limited to novel label trials only, and thus not extend to familiar label trials. A median split was performed, based on the proportion of overlap. A median split based on the absolute number of translation equivalents rather than the proportion yielded the same groupings, as these two variables were highly correlated ($r(14)=.92, p<.001$). There were 8 infants who had less than 50% overlap ($M=34\%$ overlap), and 8 who had 50% or more overlap ($M=58\%$ overlap).

### 5.3.4.1 Familiar label trials.

On familiar label trials, there was no significant difference between high-overlap infants and low-overlap infants, $t(14)=.86, p=.40, d=.43$, two-tailed. Correlation analysis confirmed an absence of a significant relationship between performance on familiar label trials and either the percentage of translation equivalents, $r(14)=.24, p=.37$, or the number of translation equivalents, $r(14)=.27, p=.31$.

### 5.3.4.2 Novel label trials.

As predicted, for novel label trials, the low-overlap group showed significantly more disambiguation than the high-overlap group, $t(14)=3.52, p=.003, d=.18$, one-tailed (Figure 5.1). Those infants whose vocabularies overlapped the least showed a strong tendency to increase their looking to the novel object upon hearing the novel label, $M=.26, SD=.18$, $t(7)=3.89, p=.003, d=1.44$, one-tailed. Seven out of 8 infants in this group showed the pattern of looking longer to the novel object compared to baseline. The infants in the high-overlap group showed a non-significant decrease in attention to the novel object, $M=-.17, SD=.29$, $t(7)=-1.68, p=.14, d=.59$, two-tailed. Examined individually, no consistent pattern was shown amongst these infants: only 5 out of 8 infants showed the pattern of a decrease in attention to the novel object. A correlation analysis showed that the more overlapping
infants’ comprehension vocabularies were, the less infants showed disambiguation, \( r(45) = -0.55, p = 0.026 \). A similar trend was seen when the correlation was performed with the absolute number of translation equivalents rather than the percentage of total vocabulary, \( r(14) = -0.41, p = 0.11 \).

**Figure 5.1** Bilinguals’ average performance on novel label trials, and as a function of overlap group.

![Figure 5.1](image)

5.3.5 **Relationship of performance to other language variables.**

We also examined whether individual-level variables other than English vocabulary size and knowledge of translation equivalents (analyzed above) would predict infants’ performance on familiar or on novel label trials. Correlation analyses (see values in Table 5.2) showed that neither the number of English words understood, the number of Chinese words understood, the total vocabulary, nor the total conceptual vocabulary, was related to infants’ use of disambiguation or their performance on familiar label trials. Further, there
was no relationship between performance on either type of trial and how much English infants heard. A balance score was calculated as 50 minus the difference in exposure between the infants’ two languages (e.g. infants with perfectly balanced exposure of 50/50 had a score of 50-50=0, while those with the largest imbalance of 75/25 had a score of 75-25=50). No significant correlation was found between infants’ balance score and their performance on familiar or on novel label trials (see Table 5.2).

**Table 5.2** Correlations between language measures in comprehension vocabulary and performance on novel label and familiar label trials.

<table>
<thead>
<tr>
<th></th>
<th>Familiar label trial performance</th>
<th>Novel label trial performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Translation equivalents</td>
<td>.24</td>
<td>-.55*</td>
</tr>
<tr>
<td># Translation equivalent pairs</td>
<td>.27</td>
<td>-.41</td>
</tr>
<tr>
<td>English comprehension</td>
<td>.36</td>
<td>-.17</td>
</tr>
<tr>
<td>Chinese comprehension</td>
<td>.11</td>
<td>-.31</td>
</tr>
<tr>
<td>Total comprehension</td>
<td>.28</td>
<td>-.40</td>
</tr>
<tr>
<td>Total conceptual</td>
<td>.32</td>
<td>-.21</td>
</tr>
<tr>
<td>% English exposure</td>
<td>.33</td>
<td>-.09</td>
</tr>
<tr>
<td>Balance score</td>
<td>.24</td>
<td>-.12</td>
</tr>
</tbody>
</table>

* p<.05

### 5.4 Discussion

The current study investigated whether bilingual infants’ ability to disambiguate a novel noun can be explained by the structure of their lexicons. Seventeen and 18-month-old English-Chinese bilingual infants participated in a looking-time eye tracking study. In a preferential looking task, control trials asked infants to find the referent of a known noun
(e.g. “Look at the ball!”). On disambiguation trials, they were asked to find the referent of a novel noun (e.g. “Look at the nil!”) when given the choice between a novel object and a familiar distracter. As a group, infants showed no significant tendency to disambiguate the novel noun, but their highly variable performance facilitated an examination of whether individual differences in vocabulary structure or vocabulary size predicted their performance.

We tested the hypothesis that the development of disambiguation is related to the structure of the developing lexicon. In the case of monolingual infants, as they learn new words, infants accrue mounting evidence for a one-to-one mapping between words and concepts. However, bilinguals often learn translation equivalents (cross-language synonyms), which result in many-to-one mappings rather than a one-to-one mappings between word and concept. Thus, we predicted that at 17-18 months, bilinguals who knew many translation equivalents (high overlap group) would not use disambiguation, while bilingual infants who knew relatively few translation equivalents (low overlap group) would show disambiguation.

To quantify overlap, we measured infants’ knowledge of translation equivalents in their receptive vocabularies as a percentage of the total number of words they understood. Consistent with our predictions, those bilingual infants whose vocabularies overlapped little (knew translation equivalents for less than 50% of the words in their vocabularies) successfully disambiguated the novel noun, while those with highly overlapping vocabularies (knew translation equivalents for more than half of the words in their vocabularies) failed to disambiguate the novel noun. Correlation analyses revealed a stronger relationship between disambiguation and the percentage of translation equivalents, than between disambiguation and the absolute number of translation equivalents. The concurrent correlation between the absolute and the percentage of
translation equivalents that infants knew makes it difficult to ascertain whether absolute or percentage is the best predictor. In either case, the results provide strong support for the prediction from the lexicon structure hypothesis of a negative correlation between translation equivalents and disambiguation.

Before continuing further, it is important to rule out potential alternate explanations for these results. One alternate explanation is that some other correlated aspect of bilinguals’ vocabularies, rather than their knowledge of translation equivalents, explains the differences in infants’ performance on the disambiguation task. However, our analyses revealed that infants’ propensity to disambiguate the novel noun was not significantly correlated with any other language measure including amount of exposure to each language, relative exposure to each language (balance), total vocabulary size, vocabulary size in each language, and measures of productive vocabulary.

A second alternate explanation is that infants who know many translation equivalents did not disambiguate the novel noun because of more generalized difficulty in performing a preferential looking task. This seems unlikely because, as a group, infants were successful at looking to the familiar object in response to its label. Performance on familiar label trials did not vary as a function of the proportion of translation equivalents infants knew, but instead was most closely related to their English vocabulary size. Those infants who knew more English words and thus were likely more proficient in English were more successful in the familiar label task. But importantly, English vocabulary size did not predict performance on novel label trials.

A final alternate explanation is that disambiguation and knowledge of translation equivalents are correlated because bilinguals who adhere strongly to disambiguation avoid learning translation equivalents, while those with a weak disambiguation bias do not. Although this explanation can account for the differences seen between the high-overlap,
and the low-overlap groups of bilinguals, it does not account for the overall differences seen between monolingual and bilingual infants in their use of disambiguation. Only the lexicon structure hypothesis gives a parsimonious account of why monolinguals and bilinguals differ in their development of disambiguation, and of why differences are seen within bilingual infants as a function of their knowledge of translation equivalents. Having considered these three alternate explanations, we conclude that the current data are most consistent with the lexicon structure hypothesis.

5.4.1 The development of disambiguation.

The basic finding of this study replicates previous work showing that, as a group, bilinguals in the middle of their second year of life do not use disambiguation (Byers-Heinlein & Werker, 2009; Houston-Price et al., 2010), but monolinguals tested at the same age can successfully disambiguate novel words (Byers-Heinlein & Werker, 2009; Halberda, 2003; Houston-Price et al., 2010). However, here we show that for bilinguals, failure is not categorical. Rather, their individual success or failure can be predicted by the structure of their lexicons. Those bilinguals with lexicons closer to a one-to-one mapping structure did show disambiguation, while those infants who know many translation equivalents and thus had more many-to-one mappings in their lexicons did not use disambiguation. Bilinguals are therefore not a homogeneous group when it comes to the development of disambiguation, and this finding might help explain previously puzzling results, wherein some studies have found marginal evidence of bilinguals’ use of disambiguation (Byers-Heinlein & Werker, 2009), while other similar studies have failed to find any evidence of disambiguation by bilingual infants (Houston-Price et al., 2010).

The current study also speaks more broadly to the development of word learning heuristics. These results provide a unified account of the development of disambiguation across both monolingual and bilingual infants: disambiguation develops in infants whose
lexicons are consistent with a one-to-one relationship between words and their referents. This demonstrates how word learning heuristics can be built upon early vocabulary learning, and at the same time explains why disambiguation is not seen in infants at the very earliest stages of word learning. Before infants have learned enough words, they do not have enough evidence of the one-to-one relationship between words and their referents to drive the development of disambiguation.

5.4.2 Explaining developmental patterns of disambiguation by bilinguals.

The current study provides evidence that a one-to-one organization between word and concept is necessary to develop disambiguation. Yet, studies of translation equivalents in bilinguals have suggested that as they grow older, bilinguals tend to know more and more translation equivalents (De Houwer et al., 2006). Based on these observations, it is reasonable to predict that bilinguals would never develop the ability to disambiguate novel nouns. Yet, bilingual preschoolers do use disambiguation and related word learning heuristics, although in some cases less consistently than same-aged monolinguals do (Davidson et al., 1997; Diesendruck, 2005; Frank & Poulin-Dubois, 2002; Merriman & Kutlesic, 1993; Merriman & Kutlesic, 1993). The mismatch between this theoretical prediction and the empirical findings must be explained.

5.4.2.1 Convergent routes to disambiguation.

One possible explanation for bilinguals’ early failure at disambiguation and later success is that early and late disambiguation represent the operation of different, albeit convergent, mechanisms. As Halberda (2003, p.341) has pointed out in relation to disambiguation, “Certainly, word-learners have access to multiple strategies... it is possible that different animals and different word-learners may rely on unique processes to attain the same goal.” Consistent with this idea is research showing that children’s disambiguation
ability becomes increasingly sophisticated with development. By age 3 children can disambiguate not only the meaning of a novel noun, but also the meaning of a novel verb (Golinkoff, Jacquet, Hirsh-Pasek, & Nandakumar, 1996). Further, preschool children are able to pull from multiple sources of information, for example taking into account information about the class of a word (i.e. count nouns versus proper nouns) in their use of disambiguation (Hall, Quantz, & Persoage, 2000). Preschoolers are also able to consider pragmatic information, such as a speaker’s knowledge or ignorance, in disambiguating a novel noun (Diesendruck & Markson, 2001; Diesendruck, 2005; Diesendruck, Hall, & Graham, 2006).

We suggest that while early disambiguation develops when infants have a lexicon that primarily follows a one-to-one mapping structure (which is inherent to the monolingual but not always to the bilingual lexicon) preschoolers might have access to one or more additional routes to disambiguation. Early disambiguation might be largely implicit, but preschoolers could use explicit reasoning to disambiguate novel words. This reasoning might be socio-pragmatic in nature (e.g. “If she had wanted the shoe she would have said shoe but she didn’t so she must want the other one”) or cognitive in nature (e.g. “This one already has an English name, so nil must mean the other one”), but is available to some degree to both monolingual and bilingual children. It is also possible that, in preschoolers, disambiguation can be achieved either through the earlier or the later-developing route, depending on the demands of the task at hand. Speculations about the exact nature of this later-developing mechanism of disambiguation, whether earlier and later-developing mechanisms underlying disambiguation have similar underlying computational structures (e.g. disjunctive syllogism; Halberda, 2003, 2006), and when each mechanism might be used in word learning, are beyond the scope of this paper, but will prove fruitful questions for future research.
5.4.2.2 Disambiguation and the organization of the bilingual lexicon.

Invoking a second route to disambiguation is not the only way to explain the bilingual pattern of early failure to disambiguate novel words and later success, given increasing knowledge over time of translation equivalents. Rather than a change in the mechanism underlying disambiguation, it may be that there are changes in the bilingual lexicon that allow the same mechanism used early on by monolinguals to also be used at a later age by bilinguals. Although initially a many-to-one mapping structure in the bilingual lexicon could prevent the development of disambiguation, later changes either in the bilingual lexicon or in bilingual children’s metalinguistic knowledge might help them to better recognize that generally a single word labels each concept in each language.

Some previous research with older bilinguals has investigated whether they disambiguate novel words in a way that is consistent with concepts having a label in each language. Appropriately, preschool and school-aged bilinguals do tend to associate a novel noun with a novel object only when the distracter object has a label in that same language (within-language disambiguation), but not when two labels are in different languages (between-language disambiguation; Au & Glusman, 1990). It may be the case that it is only when bilinguals have a more sophisticated lexical structure, or only when they have reach an explicit understanding that they are learning two languages, that they are able to reliably use disambiguation, and use it appropriately (i.e. within a language but not between languages).

What do we know about the organization of the early bilingual lexicon, and bilingual children’s recognition of their two languages as being distinct? Ironically, much of the evidence that has been put forward as revealing the organization of the early bilingual lexicon has assumed that word learning heuristics such as disambiguation are available to monolinguals and bilinguals from the same point in development. If disambiguation was
available to bilinguals very early in development, examining how many translation equivalents bilinguals know would be revealing of the underlying structure of their lexicons. A number of researchers have argued that young bilinguals know few translation equivalents. This has been taken as evidence that disambiguation has “prevented” the learning of these cross-language synonyms, revealing a lexicon that does not differentiate between the bilinguals’ two languages (Clark, 1987, 1993; Volterra & Taeschner, 1978). Conversely, other researchers have reported that bilinguals know many translation equivalents (Holowka, Brosseau-Lapré, & Petitto, 2002; Pearson et al., 1995; Yip & Matthews, 2007). They argue that bilinguals must therefore have separate lexicons for each language, otherwise heuristics like disambiguation would have impeded the learning of these translation equivalents.

Both of these arguments about the nature of the early bilingual lexicon assume that disambiguation influences bilinguals’ learning of translation equivalents. But the current paper provides evidence that causality runs in the other direction: knowledge of translation equivalents influences the emergence of disambiguation. Under previous reasoning, studying bilinguals’ knowledge of translation equivalents could reveal their lexicon structure. We instead suggest that studying bilingual infants’ use of disambiguation can reveal their lexicon structure, and their growing metalinguistic knowledge of their two languages. Specifically, knowledge of translation equivalents might prevent the development of disambiguation until a lexical reorganization occurs, at which point bilingual infants’ lexicons could better support the principle that each object tends to have one basic level label in each language. Similarly, the use of disambiguation by bilinguals might mark a transition to explicit knowledge on the part of the children that they are acquiring two languages (see Genesee, Nicoladis, & Paradis, 1995; Genesee, Boivin, & Nicoladis, 1996, for evidence of pragmatic differentiation of their two languages by bilingual
toddlers). At this point children might begin to use disambiguation appropriately within a language, and may actively seek translation equivalents for words they already know. Thus, a shift from an absence of a disambiguation heuristic to the presence of one could signal a shift in the structure of the bilingual lexicon to one that can better separate words from the two languages, or to more explicit awareness on the part of bilingual children that they are acquiring two languages. Studies of within-language and between-language disambiguation using similar procedures for younger and older bilingual children, and longitudinal studies, could test these possibilities. Such studies might be simultaneously informative about word learning heuristics as well as the structure of the developing bilingual lexicon.

5.5 Conclusions

The results of this study confirm previous findings that the disambiguation word learning heuristic is not always used at the same age by bilingual infants as it is by monolingual infants. Unlike monolinguals who tend to know a single label for each referent (one-to-one mappings), bilinguals tend to know translation equivalents (cross-language synonyms) from early in development, which represent a many-to-one relationship between words and their referents. The lexicon structure hypothesis posits that disambiguation develops as a function of a one-to-one mapping structure of the lexicon. We directly tested this hypothesis, by examining whether knowledge of translation equivalents can account for bilinguals’ overall later development of disambiguation as compared to monolinguals. Our results showed that, in general, those bilinguals who knew relatively few translation equivalents disambiguated a novel word, while those who knew many translation equivalents did not. Thus, differences both between monolinguals and bilinguals, and also between different groups of bilinguals can be explained by the structure of the developing lexicon. Whether monolingual or bilingual, only those infants whose
lexicons roughly followed a one-to-one mapping structure between word and concept had developed disambiguation at 17-18 months.

Paradoxically, there is evidence that bilinguals do use disambiguation later in development, even though their knowledge of translation equivalents grows as they continue to learn words. In this paper, we raised two possible explanations for this developmental pattern: 1) the development of a second mechanism not reliant on a one-to-one lexical structure that allows children to disambiguate novel words and 2) a growing understanding on the part of bilinguals that each object has a label in each language. Future studies will be needed to test each of these possibilities. The current research direction not only contributes to our understanding of the developmental origins of disambiguation, but more generally illuminates word learning and lexical development across infants from both monolingual and bilingual backgrounds.
5.6 References

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6 Conclusions

To learn their native language, infants use a broad set of tools, which flexibly provide the support to acquire any of the world’s languages. This thesis focused on the fascinating case of infants acquiring two languages simultaneously from birth. Four sets of studies were undertaken that compared infants growing up monolingual to infants growing up bilingual, to better understand how the tools of language acquisition develop and are used across very different early language contexts. In this section, I will first address the immediate implications of each set of studies, and closely-tied directions of future research. I will then discuss the limitations of this line of inquiry. Finally, I will turn to the broader issues raised by this thesis, addressing directions that future research with bilinguals might take in helping to illuminate language acquisition across all infants.

6.1 Summary of results and implications

The studies presented in Chapter 2 build upon research showing precocious speech perception abilities in newborn infants. It has previously been demonstrated that infants not only have a preference for speech sounds over non-speech sounds from birth (Vouloumanos & Werker, 2007), but also show a further fine-grained preference for the native language over an unfamiliar language (Mehler et al., 1988; Moon, Cooper, & Fifer, 1993). Chapter 2 probed the boundaries of infants’ native language perception by comparing newborn infants exposed to two languages prenatally (bilinguals) to infants exposed to a single language prenatally (monolinguals). Results from monolingual infants replicated previous findings that newborn monolinguals have learned about their native language prenatally. Results from bilingual infants provided compelling evidence that it is equally feasible for infants to learn about two native languages prenatally as it is for them to learn about one.
Past studies have shown that, as early as 4-months-of-age, both bilingual and monolingual infants demonstrate patterns of behavior that reflect the specific nature of their language environments (Bosch & Sebastián-Gallés, 1997; Bosch & Sebastián-Gallés, 2001). The results presented in Chapter 2 indicate that monolingual and bilingual development diverge even earlier, from birth in the case of infants who have had either monolingual or bilingual prenatal experience. However, it is not the case that prenatal bilingual experience is confusing to infants. Rather, this set of studies shows that bilingual newborns are well-prepared for the challenges of bilingual acquisition. They demonstrate interest in both of their native languages, and direct attention preferentially to these languages. Further, results presented in this thesis show that, at least when the languages are from different rhythmic classes, bilinguals maintain an ability to discriminate their two native languages, which can support bilingual infants as they build two language systems. Thus, early-appearing sensitivity to languages that differ rhythmically are not overwritten by bilingual experience, but rather infants from different language backgrounds share a robust perceptual capacity for language discrimination and early learning about the properties of the native language or languages.

The results presented in Chapter 2 raise important questions about how newborn infants perceive and process speech. Theories of sentence perception by newborns have focused on their sensitivity to rhythmical information. It has been proposed that newborns do not readily perceive differences between languages within the same rhythmical class (Mehler et al., 1988; Mehler, Dupoux, Nazzi, & Dehaene-Lambertz, 1996; Nazzi, Bertoncini, & Mehler, 1998; Ramus, Hauser, Miller, Morris, & Mehler, 2000). Studies presented in Chapter 2 show that bilingual newborns learning languages from the same pair of rhythmical classes – English-Tagalog bilinguals and English-Chinese bilinguals – have
different patterns of preference for English versus Tagalog. This difference in perception is not predicted by current theories of language discrimination in newborns.

There are several different ways that this apparent within-rhythmic class sensitivity might be explained. First, it could be that in general, newborn infants are more sensitive to within-class rhythmic distinctions than previously thought. Tagalog and Chinese are not rhythmically identical, and newborns might pick up on this difference. A second possibility is that newborn infants are sensitive to non-rhythmic differences between languages, differences which have not previously been manipulated in experimental studies. In the case of the experimental languages investigated in Chapter 2, Chinese has lexical tone and Tagalog does not. It is an open question as to how newborn infants perceive lexical tone, and whether they are able to discriminate between tone languages and non-tone languages. A final possibility is that sensitivity to differences between languages is enhanced in bilingual infants because of their very early experience with multiple languages. Exploring each of these possibilities might ultimately uncover a variety of tools that bilingual infants can use to acquire different language pairs.

After speech perception capacities are honed during the first year of life, infants move towards the important task of building their vocabularies. Chapter 3 investigated the development of an important and powerful word learning tool: the ability to form an associative link between a word and an object, and whether infants’ use of this tool differs across monolinguals and bilinguals. The studies in this chapter used a tightly-controlled laboratory method called the Switch task to test infants’ association of two dissimilar-sounding words (lif and neem) with two perceptually different objects. These studies indicate that both monolingual and bilingual infants fail to form an association at 12-months-of-age, but succeed at 14-months-of-age. This identical developmental trajectory helps to explain why lexical development in monolingual and bilingual infants is highly
similar (Pearson, Fernández, & Oller, 1993; Pearson, Fernández, Lewedeg, & Oller, 1997; Umbel, Pearson, Fernández, & Oller, 1992). Necessary, although perhaps not sufficient for word learning, these studies suggest that the fundamental ability to link word and object develops on the same schedule across infants from very different language backgrounds.

These findings provide an important context for interpreting previous experimental results showing that, under some circumstances, bilinguals are later than monolinguals in developing the ability to learn minimal-pair words (e.g. *bih* and *dih*) in the Switch task (Fennell, Byers-Heinlein, & Werker, 2007; Mattock, Polka, Rvachew, & Krehm, 2010). Given the results presented in Chapter 3, it is possible to conclude that this difference originates in bilinguals’ ability to encode and access phonetic detail as they learn new words, rather than a more generalized difficulty in forming word-object associations.

Ongoing work in the area of minimal pair word learning also provides impetus for future studies of bilinguals’ learning of dissimilar-sounding words. Several studies have shown that providing sentential context and referential cues can boost monolingual infants’ learning of minimal-pair words (Fennell & Waxman, in press). Evidence is emerging that bilinguals might be particularly aided by sentential context in minimal-pair word learning tasks (Fennell & Byers-Heinlein, 2009). This could be because of the additional challenges that bilinguals must overcome in naturalistic word learning situations. While monolinguals can assume that new words they encounter belong to their native language (see Bijeljac-Babic, Nassarally, Havy, & Nazi, 2009, for evidence that monolinguals can rapidly learn words in a foreign language), bilinguals might first attempt to ascertain which of their two languages is being spoken before learning a new word. Thus, sentential context might prove to be a tool that boosts word learning performance both for minimal-pair words and for dissimilar-sounding words. Future studies comparing monolinguals and bilinguals on
associative word learning could investigate how infants take advantage of the specific word learning context, and in particular sentential context, to form word-object associations.

Forming an association between a word and an object, as tested in Chapter 3, is necessary across many types of word learning situations. Other tools that infants use to learn new words are more specific to particular circumstances. Word learning heuristics are thought to be a type of tool that children use when the reference of a novel word is ambiguous. Chapter 4 probed the development of one such heuristic, the disambiguation of a novel noun by associating it with a novel rather than with a familiar object. The study asked whether disambiguation emerges as a result of maturation and/or general language experience, or instead through experience with a particular type of language input. To this end, age-matched monolingual, bilingual, and trilingual infants were tested in the same disambiguation task. Results showed that infants' use of disambiguation varied as a function of language experience: the more languages being learned by the infant, the less evidence there was for the infant having developed disambiguation. This provides compelling evidence that the particular type of early language environment is important with respect to the developmental time course of disambiguation.

Chapter 4 raised the lexicon structure hypothesis, positing that infants develop disambiguation as they gain mounting evidence in their lexicons for a one-to-one relationship between words and their referents. Under this hypothesis, bilingual and trilinguals are less likely to show disambiguation than are monolinguals, as they typically encounter multiple labels for the same thing (one in each of their languages). Chapter 5 provided a direct test for this hypothesis, by relating bilinguals’ knowledge of translation equivalents (cross-language synonyms) to their use of disambiguation. Strong evidence supporting the lexicon structure hypothesis was found: those bilinguals who knew few translation equivalents showed disambiguation, while those who knew many translation equivalents
equivalents did not. Thus, Chapter 5 pinpointed the aspect of bilingual experience that causes differences in the development of disambiguation relative to monolingual infants. Chapters 4 and 5 together provide a parsimonious explanation for how disambiguation develops across infants from different language backgrounds.

Given the finding that disambiguation is not available to bilinguals at the same age as it is available to monolinguals, one might wonder how bilingual infants cope without this tool for word learning. Certainly, it is not the case that bilingual infants are impaired in lexical acquisition, as age-matched monolinguals and bilinguals know similar numbers of words, and have lexicalized a similar number of concepts (Pearson et al., 1993; Pearson et al., 1997; Umbel et al., 1992). One possibility is that situations in which disambiguation would be useful are not frequent in real word learning contexts. Perhaps disambiguation does not provide necessary or additional information about the referent of a novel word very often even for monolingual children. Indeed, there are many rich cues to reference in the language learning environment, from social cues given by the interlocutor, to patterns of co-occurrence across time between word and object. It may be that disambiguation is a simply a byproduct of the organization of the word learning system, as opposed to an important source of referential information for young word learners.

Alternately, it could be that bilingual children have advanced word learning and cognitive abilities that allow them to overcome the unavailability of the disambiguation word learning heuristic. For example, there is evidence that bilingual children are precocious in their theory of mind development (Goetz, 2003; Kovács, 2009). Enhanced theory of mind might give bilinguals better access to a speaker's intentions, in turn providing information about the intended referent of a novel word. There is also work showing that, as early as 7 months-of-age, bilingual children show some cognitive advantages. These include an enhanced ability in bilinguals to inhibit a previously learned
regularity (Kovács & Mehler, 2009a). This could prove useful when infants posit an initially incorrect mapping between word and referent, which must later be corrected. There is other evidence that 12-month-old bilinguals are more able than monolingual infants to track multiple regularities simultaneously (Kovács & Mehler, 2009b). This could be of benefit when multiple novel words are encountered in fast succession. Bilinguals might show better facility than monolinguals in tracking the meanings of multiple words simultaneously. Such a possibility could be tested by comparing monolinguals’ and bilinguals’ ability to monitor cross-situational statistics of co-occurrence between words and objects (e.g. Smith & Yu, 2008; Vouloumanos & Werker, 2009).

The current studies on bilinguals’ early use of disambiguation can also be considered in light of the broader mutual exclusivity framework. Mutual exclusivity proposes that children assume that each object has only one basic level label (Markman & Wachtel, 1988). As a consequence, when confronted with a label in the context of an object with a known name, children will show a variety of behaviors to avoid mapping the same object with two basic-level labels, of which disambiguation is but one such behavior. Other behaviors include associating the new label with a part of the name-known object (Markman & Wachtel, 1988), and, particularly when given consistent syntactic cues, inferring that the novel word refers to a material-kind property of the object (Hall, Waxman, & Hurwitz, 1993) or that it is a proper name for that object (Hall, 1991). Bilingual preschoolers have shown evidence of inferring that a novel label refers to an object part rather than the entirety of a name-known object, although their tendency appears weaker than that of monolinguals (Davidson & Tell, 2005).

Given the current finding that greater knowledge of translation equivalents predicts less use of disambiguation amongst bilinguals, it would be interesting to investigate whether knowledge of translation equivalents also predicts these other mutual exclusivity
behaviors. Such a finding would support the mutual exclusivity framework, and could broaden the current claims about the role of the lexicon structure in the development of multiple word learning heuristics related to mutual exclusivity. Conversely an absence of a relationship between translation equivalents and other mutual exclusivity-related behaviors would suggest that the principle of mutual exclusivity does not underlie early use of the disambiguation word learning heuristic.

6.2 Limitations

Infants growing up bilingual are a fascinating population for study, and in comparing their development to infants growing up monolingual, we gain a unique window into language acquisition. However, any results from studies comparing monolingual and bilingual infants must be interpreted carefully and in light of the different natures of these two populations. It is important to remember that bilingualism is not a randomly-assigned variable, but rather arises due to parental circumstance and choice. For example, immigrant parents are often bilingual, and thus have the opportunity to pass two languages to their children if they so choose. Bilingualism is thus often correlated with a multitude of other variables. In Vancouver, where the current studies were conducted, bilingual populations are extremely ethnically and culturally diverse. In contrast, the monolingual English-speaking population is typically Canadian-born, and tends to share traditional Canadian values and culture. Thus, there are likely a host of differences between the two groups, not only the languages spoken at home, but also in terms of parenting, nutrition, family organization, and many other variables. It is important to consider whether any of these third variables is more likely to account for the patterns of results reported, rather than the variable of interest which is monolingual versus bilingual experience.

The concerns about third-variable explanations can be partially assuaged. Most participating infants, whether monolingual or bilingual, came from middle to upper-middle
class families, which share many common values and practices regardless of cultural background. Parents were typically highly motivated to provide a rich environment for their infants’ development, which is central to ensuring successful language acquisition. Also, results of the studies in this thesis suggested that there were not generalized differences in language acquisition between monolinguals and bilinguals, but rather differences were limited to certain tasks. For example, Chapter 3 showed that monolinguals and bilinguals have an identical developmental trajectory in terms of associative word learning. This supports the position that there is no general language advantage or delay for either group. Similarly, in Chapters 4 and 5, infants were tested both on their ability to recognize familiar words, and their ability disambiguate a novel word. Monolinguals and bilinguals differed only in disambiguation and not in familiar word recognition, a finding that is best explained by infants’ language experience (monolingual versus bilingual) specifically affecting disambiguation, rather than some third variable that would likely affect infants’ performance on both tasks.

Not only is the context of acquisition different between monolingual and bilingual infants, but there is also considerable heterogeneity within the larger group of infants considered bilingual. In some cases (Chapters 3 and 4), the bilinguals tested were heterogeneous with respect to the particular language pair they were acquiring. It is conceivable that word learning is differentially challenging in the context of particular language pairs (although see Fennell et al., 2007, for a study of word learning in which similar results were replicated across three groups of bilingual infants). It is also the case that infants’ relative proficiency in each language varied. Bilingual infants heard each language between 25% and 75% of the time, but some infants had very balanced exposure (e.g. 50/50) while for others exposure was unbalanced. Further, infants heard each of their languages across different contexts. For example, some infants were growing up in a one-
parent-one-language situation, while for others both parents were bilingual. The current studies cannot fully address these within-group differences, as sample sizes did not typically permit the subdivision of the bilingual group to look at more fine-grained differences amongst these infants. However, Chapter 5 did examine whether individual differences amongst bilingual infants (i.e. their knowledge of translation equivalents) could account for their disambiguation behavior. Future studies could use a similar approach.

6.3 Future directions

The studies presented in this thesis represent only the tip of the iceberg of comparisons between monolinguals and bilinguals that could provide important insights into language acquisition. Building from previous work, these studies ask how the same tools important for monolingual acquisition develop in bilingual environments. There is certainly enormous room for future studies in the same vein. Novel insights might also be found by motivating studies in light of the particular acquisition tasks that are faced by bilingual infants, and the tools that will thus be necessary for successful acquisition in bilingual contexts. For example, unique to bilinguals is the task of ascertaining which, if either, of their two languages is being spoken in a given situation, whereas monolingual infants need only determine whether their own familiar language or a foreign language is being heard. Future studies might examine how this affects infants’ approach to language tasks.

There are also unique characteristics of bilingual language environments that could provide fruitful avenues of inquiry. Typically, experimental studies of bilingual acquisition quantify the amount of exposure to each language, but have less often investigated the qualitative aspects of their exposure. For example, some bilingual infants hear sentences that are mixed with respect to their two languages, as in code switching and borrowing (see Byers-Heinlein, 2009, for a preliminary investigation of this topic). Experience with mixed
language could affect acquisition strategies. Further, the studies that comprise this thesis (as well as other previous work with bilinguals) have presented stimuli in a single language. However, it would also be of theoretical interest to investigate tools that bilingual infants use to cope with mixed language in experimental paradigms. Such work would provide further insight into how tools important for navigating a bilingual versus a monolingual environment might diverge across development.

An important future direction for studies of infant bilingualism is research that better addresses the question of how bilinguals discriminate, separate, and ultimately represent their two languages. The beginnings of these questions were addressed in this thesis. Chapter 2 demonstrated that, at a perceptual level, newborn bilinguals are able to discriminate the two languages in their environment, and this discrimination ability persists at least several months into development (Bosch & Sebastián-Gallés, 1997; Bosch & Sebastián-Gallés, 2001; Weikum et al., 2007). To fully understand bilingual development, it is important to know how and when infants go beyond discrimination to true separation and the setting-up of two different language systems. As suggested in Chapter 5, studies of the developmental trajectory of disambiguation could help to reveal how bilingual infants organize the words of each of their languages. Studies are needed to examine language separation across a variety of language systems, including at the phonetic, lexical, and syntactic levels.

6.4 Concluding statement

Bilingual and monolingual infants have the same ultimate goal: that of learning their native language or languages. Regardless of language background, infants must use those tools that are available as best they can, and develop other tools that are useful in the context of their language learning environments. This thesis has demonstrated how some tools develop and are used robustly across monolingual and bilingual environments. These
include early attention to the native language or languages, the discrimination of rhythmically different languages, and the ability to form an associative connection between a word and an object. However, other tools build upon specific types of language experience, resulting in different developmental patterns across monolingual and bilingual infants. In particular, the ability to disambiguate a novel word develops when infants’ lexicons support a notion of one-to-one mapping between word and referent, and thus does not emerge on the same schedule in bilingual infants who know many translation equivalents. It might thus be necessary for bilinguals to rely more heavily on other tools to achieve the same progress in lexical development as their monolingual peers. Together, the studies presented in this thesis provide a fascinating window on how infants cope with diverse early language environments.
6.5 References


# Appendix 1

The University of British Columbia  
Office of Research Services  
Behavioural Research Ethics Board  
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

## CERTIFICATE OF APPROVAL - MINIMAL RISK RENEWAL

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<th>DEPARTMENT:</th>
<th>UBC BREB NUMBER:</th>
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<tr>
<td>Janet F. Werker</td>
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<td>H01-80381</td>
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<td>Katherine Yoshida</td>
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The Annual Renewal for Study have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board

Dr. M. Judith Lynam, Chair  
Dr. Ken Craig, Chair  
Dr. Jim Rupert, Associate Chair  
Dr. Laurie Ford, Associate Chair  
Dr. Anita Ho, Associate Chair
CERTIFICATE OF APPROVAL- MINIMAL RISK RENEWAL

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Approval is issued on behalf of the Behavioural Research Ethics Board.
Appendix 3

Language background information for multilingual participants in Chapter 3, Study 1.

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# Certificate of Approval

**Principal Investigator:** Werker, J.F.  
**Department:** Psychology  
**Number:** B04-0441

**Institution(s) Where Research Will Be Carried Out:**  
Children's & Women's Health Centre, Providence Health Care, UBC Campus

**Co-Investigators:**  
Byers-Heinlein, Krista, Psychology; Cruickshank, Marisa, Psychology; Fennell, Christopher, Psychology; Weikum, Whitney, Psychology; Yeung, Henry, Psychology; Yoshida, Katherine, Psychology

**Sponsoring Agencies:**  
Social Sciences & Humanities Research Council

**Title:**  
Bilingualism and Enculturation: Roots in Infancy

**Approval Expiry Date:** JUL 5, 2002  
**Term (Years):** 1

**Certification:**  
The protocol describing the above-named project has been reviewed by the Committee and the experimental procedures were found to be acceptable on ethical grounds for research involving human subjects.

---

*Approval of the Behavioural Research Ethics Board by one of the following:*

Dr. James Frankish, Chair,  
Dr. Cay Holbrook, Associate Chair,  
Dr. Susan Rowley, Associate Chair

This Certificate of Approval is valid for the above term provided there is no change in the experimental procedures.