The Effects of Language Mixing on Word Learning and Comprehension in Bilingual 3-year-olds

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A Thesis

in

The Department

of

Psychology

Presented in Partial Fulfillment of the Requirements for the Degree of Master of Arts
(Psychology) at Concordia University
Montreal, Quebec, Canada

August 2017

CONCORDIA UNIVERSITY

School of Graduate Studies

This is to certify that the thesis prepared

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Entitled: The Effects of Language Mixing on Word Learning and Comprehension in Bilingual 3-year-olds

and submitted in partial fulfillment of the requirements for the degree of

Master of Arts (Psychology)

complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

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Amel Jardak

One challenge bilingual children face in their learning environment is language mixing (Bail et al., 2015; Byers-Heinlein, 2013), which occurs when two languages appear in the same sentence or conversation. Recent research shows that children are slower to process familiar words that occur at the point of language mixing (Byers-Heinlein et al., 2017). How does language mixing in the middle of a sentence affect the comprehension and the learning of words that occur after the mixed-input? We tested 3-year-old French-English bilinguals in two studies. In Study 1, children were tested on their comprehension of a noun that occurred either in a single-language sentence (e.g., "Look! Can you find the pretty cow?") or following a mixed-language adjective (e.g., "Look! Can you find *la jolie* cow?"). We found that language mixing had no effect on the comprehension of following familiar nouns. In Study 2, children were taught two words, one in a single-language sentence (e.g., "Look! Do you see the dog on the teelo?") and one in a mixed-language sentence (e.g., "Look! Do you see the *chien* on the walem?). We found that although children could correctly identify the novel target on both single- and mixed-language sentences, they were only able to learn the novel word that was taught in a single-language sentence. These results suggest that language mixing poses a challenge to word learning. Overall, these two studies demonstrate that the effects of language mixing on language acquisition depend both on the type of mixing and the type of language task.

Acknowledgements

This work was supported by a grant from the Natural Sciences and Engineering Research Council of Canada (402470-2011) to Krista Byers-Heinlein, a grant from the National Institute of Child Health and Human Development (R03HD079779) to Casey Lew-Williams and Krista Byers-Heinlein, and a fellowship from the Fonds de Recherche du Québec – Société et Culture to Amel Jardak.

I would like thank Dr. Krista Byers-Heinlein for her constant support through the ups and downs of writing this thesis. Thank you for being an amazing role model not only as a scientist, but also as a strong woman. I would also like to thank all the members of the Concordia Infant Research Laboratory for being such an extraordinary team. A special thanks to Liz, Mel and Daphnée for being the best people with whom to have an existential crisis. Thanks to the parents and their children who participated in this study, without whom this work would not have been possible. I would also like to thank my committee members, Dr. Diane Poulin-Dubois and Dr. Natalie Phillips, for the time and effort they put into this thesis.

Thanks to my family for still loving me as I became a monster who never had time to socialize or help out with anything. Thanks to my husband for being a constant support and for always believing in me.

Contribution of Authors

This project has been possible thanks to the contribution of three authors. The studies were originally conceived by Dr. Krista Byers-Heinlein and Dr. Casey Lew-Williams. Amel Jardak designed the studies in coordination with Dr. Krista Byers-Heinlein, and Dr. Casey Lew-Williams. Amel Jardak created the stimuli, coordinated the data collection, performed the analyses, and wrote the present manuscript. Finally, Dr. Krista Byers-Heinlein provided critical feedback for all the steps mentioned above.

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The Effects of Language Mixing on Word Learning and Comprehension in Bilingual 3-year-olds

Young children are confronted with the challenging task of learning language in order to make sense of their world and communicate with others. Thankfully, they are well equipped for it (Bertoncini & Mehler, 1981; Vouloumanos & Werker, 2007). Language learning involves a variety of interrelated tasks. Children must learn to pay attention to sound contrasts that are meaningful in their native language and ignore those that are not (Jusczyk et al., 1993; Kuhl et al., 2006; Polka & Bohn, 1996; Polka & Werker, 1994). They must recognize cues that signal boundaries between words in their language (Johnson & Jusczyk, 2001; Jusczyk, 1997; Nazzi et al., 2006). They must infer what a label refers to, (Estes, Evans, Alibali, & Saffran, 2007; Gleitman & Gleitman, 1992; Shukla, White, & Aslin, 2011), and then associate the sounds of words with their meanings (Werker, Cohen, Lloyd, Casasola, & Stager, 1998; Werker & Fennell, 2004). Finally, they must process words in real-time speech (Fernald, Perfors, & Marchman, 2006; Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998; Hurtado, Marchman, & Fernald, 2007; Marchman, Fernald, & Hurtado, 2010). If this seems challenging to accomplish in one language, it is likely even more challenging for children learning two languages. One might wonder how bilingual children cope with twice the language-learning tasks without falling behind on their language development. Moreover, bilingual children face language-learning tasks that are not encountered by monolinguals. One type of speech unique to bilinguals is language mixing (Bail, Morini & Newman, 2015; Byers-Heinlein, 2013; Byers-Heinlein, Morin-Lessard, & Lew-Williams, 2017), which occurs when words from the two languages occur in the same sentence or conversation (e.g., “Look at the *chien*!”) The goal of this thesis is to better understand how bilingual children cope with language mixing in the context of familiar word recognition and novel word learning.

For the remainder of this introductory section, I will review several areas of the literature that are crucial for understanding how bilingual children might process mixed language. First, I will provide a brief introduction to the currently limited literature on how bilingual children process language mixing. Second, I will briefly describe key points about bilingual language development and how it compares to monolingual development. Third, I will discuss the literature on children's ability to process speech in real-time, and the related ability of efficient comprehension of familiar words. I will explain how these two factors could potentially be compromised by language mixing and how this may in turn affect word learning. Finally, I will describe the two empirical studies that are the focus of my thesis, investigating the effect of language mixing on recognizing and learning words that follow language mixing.

Language mixing

Bilingual individuals use two or more languages in everyday life. Although some bilinguals speak each language in different contexts (e.g., at home vs. in school), many will use both languages when interacting with other bilinguals who speak the same language pair. This practice of using more than one language within a conversation or even within a sentence is called language mixing (also sometimes called code switching; e.g., Bail et al., 2015) and is very common amongst bilingual adults (Dornic, 1980; Grosjean, 1982). Bilingual parents may also mix their languages when interacting with their children. Indeed, research has shown that many infants and toddlers are regularly exposed to language mixing from their bilingual parents (Byers-Heinlein, 2013). This occurs even amongst parents who consciously try to avoid mixing with their children (Bail et al., 2015; Goodz, 1989). When Bail and colleagues (2015) examined the speech of 24 bilingual parents interacting with their infants during a short playing session, they found that all parents were prone to language mixing and did so at least once. Moreover, some parents mixed so much that over a third of their utterances were mixed. This raises the important question of how this frequent exposure to language mixing might affect the language development of these young bilinguals.

Not much is known regarding the effects of language mixing on young bilingual learners. While initial research on this topic focused on children's production of language mixing (Lanza, 1992, 1997), there has been increasing interest in how much mixing is present in the input provided by parents to their children. Studies show that parents of bilingual children do mix with their languages (Bail et al., 2015; Goodz, 1989), and correlational evidence suggests that children whose parents do more language mixing have smaller vocabularies (Byers-Heinlein, 2013). This implies that language mixing could be a challenge to language acquisition. Other studies do not find clear links between parental language mixing and vocabulary size (Bail et al., 2015). However, published findings remain scarce and many questions remain unanswered. Most of what is known about language mixing comes from research with bilingual adults. Indeed, research with that population suggests that language mixing can cause a temporary slow-down in language processing (Grainger & Beauvillain, 1988; Meuter & Allport, 1999; Proverbio, Leoni, & Zani, 2004; Thomas & Allport, 2000). In a task where bilingual participants were shown a numeral and asked to name it either in English or in their second language, their reaction times were slower when they were instructed to name it in a different language from the previous trials (mixed-language trials) than when they were instructed to name it in the same language as the previous trials (single-language trials) (Meuter & Allport, 1999). In a comprehension task with highly proficient bilingual interpreters, participants were slower at processing mixed-language sentences compared to single-language sentences (Proverbio et al., 2004). This mixing cost in adults supports the idea that language mixing could be even more challenging for young bilinguals as they are still in the process of learning their languages.

Two areas where language mixing could be potentially challenging for children are word comprehension and word learning. Indeed, previous studies have demonstrated that mixing a familiar word can affect its comprehension by young bilinguals (Byers-Heinlein et al., 2017). In a looking-while-listening paradigm, 20-month-old French-English bilinguals were presented with two objects on a screen, a target (e.g., a dog) and a distractor (e.g., a door), and were instructed to look at the target object (dog). The label naming the target object appeared either in a single-language sentence (e.g., "Find the dog!") or in a mixed-language sentence (e.g., "Find the *chien*!"). Toddlers were less accurate to look at the target object when they heard it labeled in the mixed-language sentence than in the single-language sentence. In this case, the mixing occurred at the exact point of hearing the target word. However, language mixing can occur at any point in a sentence, raising the question of how children comprehend and learn words that are heard following language mixing. For example, in the sentence "Look! Can you find *le gentil* dog?", the target noun "dog" occurs after the mixed determiner and adjective "*le gentil*", although the noun itself is in the same language as the rest of the sentence. Does language mixing only affect comprehension of the mixed word itself, or does it also affect the processing of words that follow it? This question is important because novel words are often placed at the end of a sentence in infant directed speech (Fernald & Mazzie, 1991). Therefore, if language mixing that occurs in the middle of a sentence affects comprehension or learning of words that follow, this might impact vocabulary development.

The aim of this thesis was to investigate the effect of language mixing on children's ability to understand and learn new words that follow language mixing. The next section will provide a brief overview of language acquisition in young children and differences between monolinguals and bilinguals, in order to provide context for understanding how language mixing might affect that development.

Word learning in monolinguals and bilinguals

Word-learning is a multi-faceted task. At minimum, children must process the speech signal, identify and encode the novel word, decide what the word is referring to, and make a mental association between the word and object (Fennell, Byers-Heinlein, & Werker, 2007; Horst & Samuelson, 2008; for a review see Werker, Byers-Heinlein, & Fennell, 2007). Moreover, this must occur quickly while listening to running speech (Fernald et al., 2006; Fernald et al., 1998; Hurtado et al., 2007; Marchman et al., 2010). Nonetheless, children are excellent word learners, and begin to understand words from as early as six months of age (Bergelson & Swingley, 2012). There are many similarities between monolinguals and bilinguals as they embark on the task of learning words and building a vocabulary. The two groups begin understanding and producing words at around the same age (Holowka, Brosseau-Lapré, & Petitto, 2002). Also, when both languages are taken into account, monolinguals and bilinguals understand and produce a similar number of words (Core, Hoff, Rumiche, & Señor, 2013; Pearson, Fernández, & Oller, 1993). Laboratory research indicates that these similarities could be because their basic ability to associate a word and a referent is similar. For example, in a word-learning task where infants heard dissimilar-sounding novel words “lif” and “neem”, monolinguals and bilinguals showed similar failure to learn the two novel words at 12 months, but success at 14 months (Byers-Heinlein, Fennell, & Werker, 2013).

There is however some evidence that monolinguals and bilinguals can differ in some parts of the word learning process. For example, there are some differences in how the two groups identify and encode subtle sound differences that signal changes in word meaning. In a looking-while-listening study, monolinguals were able to learn two similar sounding words ("bih" and "dih") at 17 months (Werker, Fennell, Corcoran, & Stager, 2002), but bilinguals were only able to do so at age 20 months (Fennell et al., 2007). However, subsequent studies suggested that this was not a bilingual delay, but rather a difference. In a similar paradigm, two studies found that bilinguals performed best when learning words from a bilingual speaker, and monolinguals when learning words from a monolingual speaker (Fennell & Byers-Heinlein, 2014; Mattock, Polka, Rvachew, & Krehm, 2010). This suggested that each group learned best when the learning situation matched their everyday language environments.

Bilinguals may also differ from monolinguals in identifying the referent of a novel word. For example, mutual exclusivity refers to children's bias to associate each object with a single basic-level label (Markman & Wachtel, 1988). This is often shown via disambiguation, which is the tendency young infants have of associating a new word to a new object, and not to a familiar object (Merriman & Bowman, 1989). For example, if presented with a spoon (which is familiar) and a whisk (which might be unfamiliar) and asked "Where is the fep?", children may use mutual exclusivity to disambiguate the meaning of the novel word "fep". Because children assume that each object has one label, they will assume that "fep" must refers to the whisk, since the spoon already has a label. Mutual exclusivity is useful to monolinguals because each object does tend to have a single label in their learning environment. It is however less useful for bilinguals because each object has two labels in their learning environment – one in each language. Indeed, disambiguation is used by monolingual 17- to -18- month-olds (Byers-Heinlein & Werker, 2009; Halberda, 2003), but not as much by bilinguals of the same age (Byers-Heinlein & Werker, 2009; 2013; Houston-Price, Caloghiris, & Raviglione, 2010).

These examples show how bilingualism can affect the way children learn new words. As discussed previously, one aspect of bilingual infants' language environment that is often overlooked is their exposure to language mixing (Bail et al., 2015; Byers-Heinlein, 2013; Byers-Heinlein et al., 2017) – a phenomenon which is rarely encountered by monolinguals. While little is known about how bilingual children process language mixing, recent work from our lab has demonstrated that familiar words in mixed-language sentences are processed more slowly than those in single-language sentences (Byers-Heinlein et al., 2017). In the next section, I will discuss two reasons why a processing delay caused by language mixing might affect two important contributors to word learning: 1) the ability to process speech in real-time, and 2) the ability to use that processed speech in order to infer the meaning of a subsequent novel word.

Real-time processing of language and word comprehension in infants and toddlers

One important factor for word learning is the ability to process speech in real-time. Speech is continuous and one must not fall behind on what their interlocutor is saying to be able to follow a conversation. The average rate of a typical adult conversation is of 10 to 15 phonemes per second (Cole & Jakimik, 1980), therefore fast and efficient speech-processing is crucial to keeping up with what someone is saying. Indeed, because real-time speech is very fast, one must be able to process information as quickly as it comes, and even be able to predict the possible identity of a word before hearing the end of that word (Grosjean, 1985; Marslen-Wilson & Zwitserlood, 1989).

As infancy and early childhood are crucial periods for word-learning (Fernald et al., 2006; Ganger & Brent, 2004; Reznick & Goldfield, 1992), developing efficiency in real-time speech processing during these years is important. Children develop adult-like processing efficiency progressively (Fernald et al., 1998) and that ability has been shown to facilitate word learning (Fernald et al., 2006; Hurtado et al., 2007; Marchman et al., 2010). In a longitudinal study, Fernald et al. (2006) documented the productive vocabulary sizes of infants at ages 15, 18, 21 and 25 months using parental report. Children were also tested in a looking-while-listening procedure where they were presented with a target and a distractor object on a screen and heard instructions to look at the target (e.g., "Where is the baby! Do you see it?"). Sometimes the target was fully named (e.g., "baby") and sometimes only the beginning of the target word was said (e.g., "*bei*"). Children who were faster and more accurate at recognizing the target word, even when only the beginning of the target word was heard, were those who showed the most accelerated growth in their productive vocabulary size during their second year. These results suggest a clear link between children's capacity to process words in real-time (measured here by children's reaction time and looking time) and their vocabulary growth (measured here by parental report).

The link between children's capacity to process words rapidly and their ability to learn new words, especially in a challenging setting, has been more directly demonstrated in a laboratory experiment (Lany, 2017). Monolingual infants aged 17 and 30 months old were tested on both a word comprehension task and a word learning task. In the comprehension task, children were presented with a familiar target object and a familiar distractor object and instructed to look at the familiar target object (e.g., "Find the doggie!"). In a subsequent word learning task, children were first taught novel words in a training phase. They were presented with an unknown object and heard instructions to look at it (e.g., "Look at the splicket!"). They were then tested on their learning of the novel words in a second phase (e.g., "Which one is the splicket?"). Infants and toddlers who were faster at recognizing the target in the word comprehension task were also better at learning novel words in the word learning task. At 17 months old, only the fastest infants during the comprehension task were able to learn the novel words. However, at 30 months old, toddlers were tested in both a challenging and a simpler word learning task. Processing speed during comprehension was related to performance in the challenging task, but not in the simpler task. Altogether, these studies demonstrate the importance of fast word processing for word comprehension and word learning in monolinguals, and how this ability improves across development.

An ability to efficiently process familiar words is not only important to comprehending the word itself, but may also be pivotal for processing subsequent information in the sentence. Children can leverage the comprehension of familiar words in the sentence to infer the identity of a novel word that occurs later in the sentence. Goodman, McDonough, & Brown (1998) investigated whether two-year-olds were able to use a known word to make inferences about a novel word later in the sentence. Toddlers heard the sentence “Mommy feeds the ferret” and were shown four objects of different semantic categories that were unknown to them (e.g., a ferret, a stirrup, a bagpipe, and a telescope). Toddlers were able to map the word “ferret” to its correct referent as it was the only novel object that could be fed. This demonstrates how familiar word comprehension early in a sentence facilitates word learning later in the sentence.

While most studies investigating real-time language processing have focused on monolinguals, there is some limited work with bilinguals. Indeed, the same relation between word processing speed and word learning has also been demonstrated in bilinguals (DeAnda et al., 2017; Legacy et al., 2016; Marchman et al., 2010). Two-and-a-half-year-old simultaneous Spanish-English bilingual toddlers were tested twice on a similar comprehension task, once in Spanish and once in English. They were shown a familiar target and a familiar distractor on the screen and were instructed to look at the target object (e.g., “Look at the dog!”). In one testing session, the instructions were all in Spanish, and in the other one, they were all in English. Toddlers' reaction times were used as an indicator of word processing speed. Their vocabulary size, which was obtained via parental report, was used as an indicator of their word learning abilities. Like with monolinguals, fast and accurate word recognition in the word comprehension task predicted toddlers' vocabulary sizes. Moreover, this relation was only true within each language, in that word processing speed in English predicted word learning abilities in English but not in Spanish and vice versa. That is, processing speed and vocabulary learning were language-specific. This demonstrates that the importance of fast and accurate word processing for word learning also extends to bilingual toddlers.

Altogether, these studies demonstrate how two factors are crucial to word learning and vocabulary development: 1) fast processing of spoken language, and 2) using a familiar word in the middle of a sentence to infer the meaning of a novel word at the end of a sentence. Conversely, difficulties with processing a familiar word early in a sentence can pose a challenge to word learning and vocabulary development. As rapid word processing and accuracy in bilinguals have been shown to be negatively affected by the mixing of a familiar word (Byers-Heinlein et al., 2017; Meuter & Allport, 1999; Proverbio, Leoni, & Zani, 2004; Thomas & Allport, 2000), we could expect that a processing delay at the point of mixing could make it difficult for the child to keep up with what a speaker is saying. Specifically, as speech is fast and continuous, a delay caused by the language mixing in the middle of the sentence (e.g., "Look at the *chien* on the ottoman!") might affect the processing of the rest of the sentence. This could in turn affect both comprehension of the familiar word (e.g., *chien*) and identification and learning of the novel word (e.g. ottoman) that follow the mixed input.

Current studies

The goal of the current thesis was to understand the effects of language mixing on children's comprehension and learning of words that occur following the mixed element. We conducted two studies with bilingual French-English three-year-olds, using a preferential looking task. Study 1 examined whether familiar words are harder for bilingual 3-year-olds to comprehend when they follow language mixing, compared to when they occur in single-language sentences. The mixed input in the context of Study 1 was a prenominal adjective and its determiner that preceded the target word (e.g., "Look at *la jolie* cow!"). We predicted that language mixing would be detrimental to children's performance, and that they would perform poorly in the mixed-language trials compared to the single-language trials. This would be evident if children looked significantly more at the target object in the single-language trials (e.g., "Look at the pretty cow!") compared to the mixed-language trials (e.g., "Look at *la jolie* cow!").

Study 2 investigated the effect of language mixing on the learning of a novel word following language mixing. We aimed to understand if it is harder for bilingual 3-year-olds to learn new words when they follow language mixing compared to when they occur in single-language sentences. The first phase of the study was a learning phase, where children were taught two novel words. One novel word always appeared in a single-language sentence (e.g., "Look! Do you see the dog on the teelo?"), and the second novel word always appeared following a one-word mix in a mixed-language sentence (e.g., "Look! Do you see the *chien* on the walem?") In this case, the one-word mix was a familiar word that gave a visual cue relevant to the identification of the target novel word. Comprehension of the mixed word was therefore necessary to for identifying and learning the following novel word. The second phase of the study was a test phase, where children were tested on their recognition of the novel words they were taught in the learning phase. Children saw the two novel objects side-by-side, and were asked to look towards one of them while their looking to each object was measured. If children looked at the target novel objet above chance in this phase, it meant that the novel word had been learned. We predicted that toddlers would learn the novel word taught in the single-language condition, but not the one taught in the mixed-language condition. Finally, we also investigated looking behaviors during the learning phase in order to better understand how the processing of language mixing affected looking behaviors during the testing phase.

Results from this thesis are important because although bilingual children regularly hear language mixing in their everyday environments, studies on the topic are limited and have relied mostly on parental report rather than directly measuring children's processing of language mixing (Bail et al., 2015; Byers-Heinlein, 2013). This project is the first to directly test children's real-time comprehension and learning of words that follow a mixed-language input. Given evidence that word processing in monolingual toddlers predicts language and cognitive skills at 8 years old (Marchman & Fernald, 2008), it is essential to study how language mixing affects familiar word processing in bilingual children (Study 1). Finally, as language mixing has been shown to incur a processing cost for familiar words (Byers-Heinlein et al., 2017), and fast word processing has been shown to predict word learning (Fernald et al., 2006; Hurtado et al., 2007; Lany, 2017; Marchman et al., 2010), it is important to experimentally investigate the impacts of language mixing on word learning (Study 2). The results from this thesis will illuminate what types of parental language practices are most conducive to successful processing of multiple languages. These results will also contribute to improved theories of bilingual language acquisition.

Study 1: Word Comprehension

Methods

Participants. Children were recruited from a database of families interested in participating in our research, principally identified via government birth lists. Twenty full-term, healthy French-English bilingual children were included in the final sample. They had an average age of 3y5m12d (range: 3y1m4d – 3y11m29d). They were 13 males and 7 females. A modified version of the Language Experience and Proficiency Questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007) was used to assess the children's language background and proficiency. Parents were asked questions about their child's experience with the languages he or she was exposed to. They were then asked to rate their child's proficiency in French and in English compared to monolingual children of the same age. A pre-determined inclusion criterion was that children had to receive a comprehension score of at least 7/10 on both languages in order to be eligible for the study. Four children also had exposure to one or two additional languages. Language dominance was established for each child as the language that had the highest comprehension score as given by parents. Ten children were dominant in English, and 10 were dominant in French. When comprehension scores were equal in both languages, the child's dominant language was considered to be the mother's dominant language. Eight children were regularly exposed to both English and French from birth, while twelve started being exposed to their second language later in life, usually when starting daycare between the ages of 6 and 18 months (see Table 1 for full details about each child's language background). Another nine children were tested but not included in the final sample due to health reasons such as low-birth weight or gestation period under 37 weeks (4), fussiness or inattention (4) or refusal to participate (1).

Children's productive vocabulary size in English was assessed using the Developmental Vocabulary Assessment for Parents (DVAP, Libertus, Odic, Feiginson, & Halberda, 2015), which consisted of a checklists of words known by children aged 2 to 18 years old based on words used in the Peabody Picture Vocabulary Test (PPVT, Dunn & Dunn, 2007). To assess children's productive vocabulary size in French, we adapted a checklist similar to the DVAP, based on words used in the Quebec French adaptation of the PPVT (Dunn, Dunn, & Thériault-Whalen, 1993). The words are ordered from easy (e.g., "boy", "chair) to hard (e.g., "honing", "angler") and parents were asked to indicate which words their child could say. A parent that was familiar with the child's vocabulary in a particular language filled out the form in that language. In some cases, each parent filled out a form in the language they usually interacted with their child in, while in other cases it was one parent who filled out both forms. One parent who wasn't familiar with the language her child used at daycare had the form filled out by the daycare worker. Of the words on the DVAP, toddlers produced an average of 76 words in their dominant language (range: 37– 177) and 52 words in their non-dominant language (range: 19 – 131), a difference which was statistically reliable, $t(36) = 2.28$, $p = .03$, $d = .74$. The total number of words produced across both languages was 115.07 words on average (range: 39–308).

Material.

Visual stimuli. Visual stimuli consisted of four pairs of animals and four pairs of inanimate objects. To ensure that they would be familiar to our 3-year-old participants, objects were chosen such that their labels were understood by at least 50% of 18-month-olds in English, and at least 50% of 16-month-olds in French according to vocabulary norms in American English (Fenson et al., 1994) and Quebec French (Boudreault, Cabirol, Trudeau, Poulin-Dubois, & Sutton, 2007). The four animate pairs were dog-bunny, froggy-cow, duck-fish, and sheepmonkey. The four inanimate pairs were apple-toothbrush, hand-door, ear-spoon, and pencil-coat. Each object was paired with another of the same animacy status so that the two would have similar visual salience. The names of the object pairs did not overlap in the word onset (i.e., started with different sounds), and had the same grammatical gender in French. Images were chosen from free online libraries, and digitally edited as necessary.

Auditory stimuli. Auditory stimuli were recorded by a female native bilingual French-English speaker with no perceptible accent in either language, who spoke using infant-directed speech. Each auditory stimulus consisted of a phrase with a target word labeling one of the objects on screen (e.g., "Look! Can you find the pretty cow?"). Each target noun was preceded by a determiner (e.g., "the") and a prenominal adjective (e.g., "pretty"). Each stimulus sentence was recorded in a single-language version where the adjective and noun were in the same language (e.g., "Look! Can you find the pretty cow?"), and a mixed-language version where the determiner and adjective were in the other language (e.g., "Look! Can you find *la jolie* cow?") Note that the target word ("cow") was always in the same language as the initial carrier phrase ("Look! Can you find…"). There were a total of four prenominal adjectives for animates (nice, pretty, good, little) and four prenominal adjectives for non-animates (new, big, large, old). They were chosen such that they 1) were not cognates across French and English, 2) did not share phonological overlap with their translation, 3) were not descriptive of one object more than another, and 4) could precede a noun in French (important because many French adjectives are post-nominal). Each adjective was always used with the same pair (e.g., the pretty/*la jolie* was always used with the froggy-cow pair). The intensity of every audio file was set at 70 dB. Parallel stimulus sets were created with the carrier sentences in English and French as in the previous example (e.g., "Regarde! Peux-tu trouver la jolie vache?"; "Regarde! Peux-tu trouver *the pretty* vache?").

Videos. Auditory and visual stimuli were combined into videos for each trial, with each trial lasting 6000 ms. During each trial, two objects appeared on the screen for the duration of the trial (one target and one distractor), while one of the stimulus sentences was played labeling the target (See Figure 1 for a schematic diagram of a sample trial). The onset of the target word occurred exactly 3000 ms into each trial. Trials were combined into four experimental orders of 24 trials, of which 8 were single-language (e.g., "Look! Can you find the good fish?"), 8 were mixed-language (e.g., "Look! Can you find *le bon* fish?"), and an additional 8 were filler trials that were also single-language. Filler trials were used reduce the overall number of trials with language mixing in the study, and were not analyzed. The language of the carrier phrase was consistent for each child (e.g. always in French or always in English), but counterbalanced across children such that half the children were tested with carrier phrases in their dominant language, and half in their non-dominant language.

Procedure. The parents and child were greeted in the parking lot by a volunteer who brought them to the laboratory playroom. While the volunteer played with the child in the playroom, the experimenter presented the laboratory and the study to the parents. Parents were given a consent form to sign and questionnaires to fill out. When the study was ready, the child and a parent were brought to the soundproof eye tracking room. A Tobii T60XL eye tracker system was used to present the stimuli and record children's eye gaze during the study. Each child sat in front of the eye tracker, either on a parent's lap, or directly on a chair while the parent sat behind them. Parents were asked to wear darkened sunglasses and headphones with music to blind them to the study condition. They were also asked not to talk or interact with the child during the study. The child was positioned approximately 60 cm away from the 24-inch monitor in a soundproof, dimly-lit room. The experimenter monitored the status of the study via the eye tracker's built-in camera and controlled the experiment from a computer in another room using Tobii Studio software. The sound was set at an average of 70 dB.

Data on children's eye gaze were collected via corneal reflection using the eye tracker system. Calibration of the eye-tracker to the child's eyes was completed prior to the main study using a built-in five-point infant calibration routine. A colourful attention getter was presented prior to the first trial and between each subsequent trial to draw the child's attention to the center of the screen. The experimenter could monitor the child's looking through a built-in camera that showed the testing room. When the child looked at the attention getter in the center of the screen, the experimenter pressed a key to start each of the 24 study trials. The total duration of the study was approximately 4 minutes.

Results

To determine if children showed successful comprehension of the target familiar words, we examined the proportion of time that they looked towards the target object on each trial. Areas of interest corresponding to a rectangle of 2 cm around each object presented on the screen (target and distractor) were defined, and children's looking was measured within those areas. Following standard approaches (Swingley, 2012), data for each trial were collapsed across a time window that began 360 ms after the onset of the target word label and ended 2000 ms after, such that the duration of the window of analysis was 1640 ms. The dependent variable of interest was the proportion of time that children looked towards the target object. This was calculated by dividing the looking time to the target object by the total time spent looking at either object (target and distractor). Trials where the child was inattentive (i.e. looked at the two objects together less than 750 ms) were excluded from the analysis. Out of 8 possible trials of each type, children completed an average of 7.40 single-language trials (range: 6–8) and 7.05 mixed-language trials (range: 4–8). Preliminary analyses found no effects of gender, order, nor language dominance on children's looking towards the target object, and therefore these factors were not included in the main analyses.

A paired samples *t*-test was conducted to compare proportion of looking to target by trial type in the mixed-language and the single-language conditions. No effect of trial type was found, $t(19) = .39$, $p = .71$, $d = .08$, indicating that children's looking to target was similar in single-language trials ($M = .76$, $SD = .09$) and mixed-language trials ($M = .75$, $SD = .14$). This suggests that their comprehension of the target word was not affected by the mixing of the non-informative adjective that preceded it. To follow-up, we conducted single-sample *t*-tests to determine if children showed above-chance recognition of the target word (chance = .5) in the different conditions. Children looked significantly above chance to the target on both the single-language trials, $t(19) = 12.80$, $p < .000$, $d = 5.87$, and the mixed-language trials, $t(19)= 8.18$, $p < .000$, $d = 3.75$, indicating a robust ability to understand the target noun in both sentence types. Results are illustrated in Figure 2.

Discussion

Study 1 tested whether the mixing of a word affected the comprehension of familiar words that follow this mixed word. On a screen, children were presented with two objects of different kinds (e.g., a fish and a duck) and were asked to look at one of them in either a single-language sentence or a mixed-language sentence. In the context of this study, each sentence consisted of a carrier phrase, a same-language or mixed prenominal adjective/determiner, and a target in the same language as the carrier phrase (e.g., "Look! Can you find the good/*le bon* fish?"). While the mixed adjective occurred immediately prior to the noun, the adjective was uninformative with respect to which object was being labeled. Results from Study 1 showed that children were equally able to understand the target word in both conditions, and no significant difference in performance on single-language trial versus mixed-language trials were found. This was not what we had predicted, yet is equally important, as it shows that not all types of language mixing affect bilingual children's language processing. One possible explanation is that only certain types and locations of language mixing affect processing. For example, a previous study found a processing cost for language mixing testing children with a mixed noun that occurred sentence-finally (Byers-Heinlein et al., 2017). This was different in several ways from Study 1. First, our mixed word was an adjective rather than a noun, and it is possible that mixing differentially affects processing of different parts of speech. Second, our mixed word occurred mid-sentence rather than occurring sentence-finally. Third, we tested children's comprehension of a word that followed the mixing, rather than the mixed word itself. Finally, in our paradigm, the mixed word was uninformative with respect to comprehending the words that followed. Take, for example, the sentence "Look at *la jolie* (the pretty) baby." If there is only one baby around, then the words *la jolie* is not necessary to determine what the speaker is referring to. However, take for example the sentence "Look at *la petite* (the small) ball." If there are two balls of different sizes around, the adjective *petite* (small) is necessary to determine to what the speaker is referring. Given these numerous potential explanations, the present results in the context of previous findings leave open the question of whether other types of language mixing are equally detrimental to children's language processing.

Study 2: Word Learning

To better understand when and how language mixing affects language learning, Study 2 tested children in a new language mixing task. We designed a word-learning paradigm where the mixed word provided information necessary for determining the reference of the sentence. It consisted of two phases: a learning phase and a test phase. In the learning phase, children saw two familiar objects sitting on top of two novel objects and heard either a single-language sentence (e.g., “Look! Do you see the bunny on the teelo?”), or a mixed-language sentence (e.g., “Look! Do you see the *lapin* on the walem?”). Children were then tested during a test phase on their learning of the novel words. The motivation for this study design was that if children have difficulty processing the mixed-language noun, they may in turn have difficulty determining the reference of the novel noun (“walem”). This would make the learning of this novel word more challenging. In this study, we use a mixed noun (as in Byers-Heinlein et al., 2017, but different from Study 1), but the noun occurred mid-sentence (as in Study 1, but different from Byers-Heinlein et al., 2017). Thus, Study 2 had interesting similarities and differences both with Study 1 and with previous investigations of bilingual children’s processing of language mixing (Byers-Heinlein et al., 2017). Finally, while the previous studies focused on familiar word comprehension, Study 2 was unique in its focus on novel word learning.

Methods

Participants. The same children who participated in Study 1 participated in Study 2 during the same visit. The order of testing was counterbalanced such that half participants were tested on Study 1 first (word comprehension), and half were tested on Study 2 first (word learning). The language of the studies was counterbalanced such as half the participants were tested in their dominant language in Study 1, and in their non-dominant language in Study 2, and the other half were tested in the non-dominant language in Study 1, and in their dominant language in Study 2. Depending on the order the child was randomly assigned to, he/she either started with Study 1, took a short break, and started Study 2, or vice versa.

Material.

Visual stimuli. Visual stimuli consisted of three animate objects that were familiar to 3-year-olds and two novel objects created for the purpose of this study. Familiar animates were chosen based on words known by at least 50% of 18-month-olds in English, and at least 50% of 16-month-olds in French according to vocabulary norms in English (Fenson et al., 1994) and Quebec French (Boudreault, Cabirol, Trudeau, Poulin-Dubois, & Sutton, 2007). Further, none of the familiar animates or their French translations had a phonological overlap at onset, nor were they cognates. Images of the animates were chosen from free online libraries. The familiar animates were a dog, a fish and a bunny, and had not been presented as stimuli in Study 1. Images of the novel objects were found on Google images and digitally modified, such that they did not resemble any known object (see Figure 3).

Auditory stimuli. Auditory stimuli were recorded by a female native bilingual French-English speaker with no perceptible accent who spoke in infant directed speech. Two nonsense words, walem (*walème* in French) and teelo (*tileau* in French), were chosen to label the novel objects. They were produced with French phonology when embedded in a French carrier phrase, and English phonology when embedded in an English carrier phrase, as judged by native speakers of each language. The two words were carefully chosen to each have two syllables, different phonological onsets, different rhymes, and to sound masculine in French. Further, their onsets were different from the familiar objects' onsets.

During the learning phrase, each auditory stimulus consisted of a carrier phrase ("Look! Do you see the…") ending with a familiar target word and a novel target word. The phrase labeled one of the animates on top of a novel object on the screen (e.g., "Look! Do you see the bunny on the teelo?"), so that children had to process the familiar word to understand the referent of the novel word. Each stimulus sentence was recorded in a single-language version where the carrier phrase, familiar target word, and novel target word were in the same language (e.g., "Look! Do you see the bunny on the teelo?"), and a mixed-language version where the familiar word was in a different language from the carrier phrase and the target novel word (e.g., "Look! Do you see the *chien* on the walem?"). The one-word language-mix was always the familiar word that preceded the mention of the novel target. The target novel word was always pronounced in the language of the carrier phrase. Each sentence was edited so that the familiar word onset occurred exactly at 4500 ms.

During the test phrase, auditory stimuli directly labeled the novel object. Sentences during this phase were all single language (e.g., "Can you find the teelo?"). Sentences were edited so that the target onset occurred exactly at 3000 ms.

The intensity of every audio file was set at 70 dB. Parallel stimulus sets were created with the carrier sentence in French (e.g., "Regarde! Vois-tu le *chien/dog* sur le tileau?" for the learning phase, and "Peux-tu trouver le tileau?" for the testing phase).

Videos. During each learning trial, the two novel objects appeared side-by-side, with a different familiar object on top of each of them (e.g. a dog on the *teelo*, and a bunny on the *walem*). After 2000 ms, the auditory stimulus directed the child to look at the familiar target atop the novel target, either in the single-language or mixed-language context. The audio for each trial ended at 6500 ms, leaving approximately 2000 ms of looking time after the target novel offset (see Figure 4 for a schematic diagram of a sample trial). The total length of each learning trial was 8500 ms.

During each test trial, only the two novel objects appeared on the screen, presented side-by-side without any familiar objects**.** The objects appeared in silence for approximately 2000 ms, then the auditory stimulus played directing children's attention to one of the object. The target word (teelo/walem) occurred exactly 3000 ms into the trial. Each test trial lasted 6000 ms. Each novel object appeared twice as a target and twice as a distractor, and side of presentation was counterbalanced both within and across children.

Experimental orders. Trials were combined into four experimental orders consisting of 12 learning trials (6 mixed-language, 6 single-language) immediately followed by 4 test trials. In the learning phrase, each novel object was consistently labeled in a single-language or in a mixed-language context, and was labeled on half of all trials in a quasi-random order. The assignment of a particular label to condition as counterbalanced across children (e.g., teelo was presented in single-language sentences for half of the children, and in a mixed-language sentences for the other half of the children). Each familiar target in the learning phase appeared eight times, such that it appeared as a target on half of the trials, and in single-language sentences on half of the trials. Novel objects appeared on every trial, half the time as a target and the other half as a distractor. Novel word and trial type were counterbalanced. The language of the carrier phrase was consistent for each child (e.g., always in French or always in English), but counterbalanced across children such that half the children were tested in their dominant language, while the other half were tested in their non-dominant language.

Procedure. All aspects of the procedure were identical as in Study 1, while using the stimuli as described for Study 2.

Results

Test phase. To determine if children successfully learned each of the words presented in the learning phase (single-language and mixed-language), we examined the proportion of time that they looked to the labeled object on each of the two test trials that each target was labeled.

Similar to Study 1, areas of interest corresponding to a rectangle of 2 cm around each object (target and distractor) were defined, and children's looking was measured within those areas. Following previous approaches (Swingley, 2012), data for each trial were collapsed across a time window that began 360 ms after the onset of the target word label and ended 2000 ms after, such that the duration of the window of analysis was 1640 ms. The dependent variable of interest was the proportion of time that children looked towards the target object. This was calculated by dividing the looking time to the target object by the total time spent looking at either object. Trials where the child was inattentive (i.e., looked at the two objects together less than 750 ms) were excluded from the analysis. Out of 2 trials of each type, children completed an average of 1.8 single-language trials (range: 1–2) and 1.55 mixed-language trials (range: 1–2). As preliminary analyses found no effects of gender, order, or language dominance on the patterns of looking to the target, these factors were not included in the main analyses.

A paired-samples *t*-test was conducted to compare proportion of looking to the target by trial type (mixed-language, single-language). We found a significant effect of trial type, $t(19) = 2.85$, $p = .01$, $d = .52$, indicating that children recognized the novel word taught in the single-language condition ($M = .62$, $SD = .26$) significantly better than the novel word taught in the mixed-language condition ($M = .43$, $SD = .28$). This suggested that the novel word taught in the mixed-language condition was harder for them to learn than the novel word taught in the single-language condition. To follow-up, we conducted single-sample *t*-tests to determine if children showed above-chance recognition of the target word (chance = .5) in each condition. Children looked significantly above chance to the target object on the single-language trials, $t(19) = 2.06$, $p = .05$, $d = .95$, indicating that they learned and recognized the novel word taught in the single-language condition. However, their proportion looking time on the mixed-language trials did not differ from chance, $t(19) = -1.12$, $p = .28$, $d = -.51$, indicating that they did not learn or recognize the novel word taught in the mixed-language condition. Together, these results suggest that the mixing of an informative familiar word makes it hard for three-year-olds to learn a novel word that follows the mixed-input. Results are illustrated in Figure 5.

Learning Phase. To better understand children's failure to learn the word presented in the mixed-language context, we investigated their looking patterns during the learning phase. We expected that language mixing would affect learning in this study as it would slow the processing of the familiar word, which in turn was necessary for determining the referent of the novel word. If language mixing indeed slowed the processing of the familiar word, then this would be indicated by less looking to the labeled familiar and novel objects during the learning phase.

We examined the proportion of time that children looked to the labeled objects on each of the learning trial. In order to do this, we measured the proportion of time children during each trial spent looking within four areas of interest representing one of the four objects on the screen: 1) familiar target, 2) novel target, 3) familiar distractor, and 4) novel distractor. As familiar objects were always on top of the novel objects, the area of interest for familiar objects corresponded to 2 cm around the sides and top of the objects. The area of interest for novel objects corresponded to 2 cm around the sides and bottom of the objects. Any overlaps in the areas of interest were attributed to the novel object. The dependent variable of interest was the amount of time children spent looking at each of the four objects presented on the screen. Note that because there were four objects on the screen with different levels of visual salience, "chance" looking cannot be set at .50, as is often done for trials where there are only two objects on the screen. Data for each trial were collapsed across a time window starting 360 ms after the familiar target onset and ending 2000 ms after the familiar target onset, such that the size of the window of analysis was 1640 ms. We calculated the child's total looking time at any of the four objects, as well as the proportion amount of time each child looked at each area of interest. Trials where the child was inattentive (i.e. looked at the four objects together less than 750 ms) were excluded from the analysis. Children contributed to the data on an average of 5.25 single-language trials (range: 2–6) and 5.55 mixed-language trials (range: 4–6) out of 6 possible trials. As preliminary analyses found no effects of gender, order or language dominance on the patterns of looking to the target, these factors were not included in the main analyses.

First, we investigated whether children in both conditions appeared to recognize the familiar word, and orient to the labeled familiar target. We also investigated whether children were able to determine the referent of the novel target, and orient towards it. We conducted paired-samples *t*-tests separately for the single-language and the mixed-language trials, investigating whether children looked more at the target object than the distractor object for both the familiar and the novel objects.

On both trial types, and for both the familiar and novel objects, children looked significantly more at the targets than the distractors. On single-language trials, children looked at the familiar target ($M = .28$, $SD = .13$) more than the familiar distractor ($M = .08$, $SD = .07$), $t(19) = 6.05$, $p < .001$, $d = 1.38$, and the novel target ($M = .52$, $SD = .15$) more than the novel distractor ($M = .11$, $SD = .12$), $t(19) = 7.07$, $p < .001$, $d = 1.73$. On mixed language trials, children also consistently looked at the familiar target ($M = .26$, $SD = .12$) more than the familiar distractor ($M = .08$, $SD = .08$), $t(19)= 5.92$, $p < .001$, $d = 1.38$, and the novel target ($M = .57$, $SD = .17$) more than the novel distractor ($M = .08$, $SD = .05$), $t(19)= 11.31$, $p < .001$, $d = 2.55$. This suggests that children had no problem recognizing the familiar target, nor the familiar novel on both trial types. Results are illustrated in Figure 6.

To directly investigate whether trial type had any effect on looking patterns during the training phase, proportion looking to the objects was analyzed with a 2 (trial type: single-language, mixed-language) x 2 (familiarity: familiar, novel) x 2 (target type: target, distractor) repeated measures ANOVA. There was a statistically significant three-way interaction between trial type, familiarity and target type, $F(1,19) = 5.27$, $p = .03$, as well as several significant lower-order effects and interactions (see Table 2). To better understand the origin of the interaction, we performed paired samples t-tests comparing children's looking during the single-language versus mixed-language trials for each of the four objects (target and distractor for both the familiar and novel objects).

First, we compared patterns of looking to the familiar objects during the two trial types. Looking to the familiar target object was similar during the single-language trials ($M = .28$, $SD = .13$) as mixed-language trials ($M = .26$, $SD = .12$), $t(19) = -.56$, $p = .58$, $d = .13$. Looking to the familiar distractor object was similar for the single-language trials ($M = .08$, $SD = .07$) as the mixed-language trials ($M = .08$, $SD = .08$), $t(19) = .29$, $p = .78$, $d = .000$. Thus for the familiar objects, the pattern of looking was highly similar across the single-language and mixed-language trials. Contrary to our predictions, we did not find evidence that language mixing affected children's processing of the familiar mixed word in this study.

However, a different pattern was observed when we explored patterns of looking to the novel objects across the two trial types. For the target novel object, there was a near-significant difference in looking time between the single- and mixed-language trials. Contrary to expectations, looking to the target novel object was marginally *greater* for children during mixed-language trials ($M = .57$, $SD = .17$) than in single-language trials ($M = .52$, $SD = .15$), $t(19) = 2.00$, $p = .06$, $d = .39$. In parallel, looking to the novel distractor was less for children in the mixed-language trials (M = .08, SD = .05) than in the single-language trials (M = .11, SD = .12), although that difference did not reach statistical significance, $t(19) = -1.35$, $p = .193$, $d = -.30$. That is, on mixed-language trials, children actually spent more time looking at the target novel object than on single-language trials. In sum, we do not find evidence that children were less able to process the familiar word and attend to the novel target in the mixed-language condition. If anything, they actually spent more time attending to the novel target object in the mixed-language condition than the single-language condition. Our results imply that children in both conditions had the necessary visual information to associate the novel label with the correct referent, even though our analysis of the test phase did not find evidence that children formed this association in the mixed-language condition.

Discussion

Study 2 investigated how language mixing affects word learning in 3-year-old French-English bilinguals. Children were taught two novel words, one presented in a single-language context, and one presented in a mixed-language context. Stimulus sentences were constructed such that children needed to process a familiar noun to deduce the referent of the novel noun, and it was the familiar noun that was either in the same language or mixed with respect to the rest of the sentence (e.g., "Look! Do you see the dog/*chien* on the teelo?") At test, children saw the the two novel objects without the familiar objects, and were instructed to look at the target (e.g., "Can you find the teelo?"). We found a significant difference in recognition of the words taught in each of the two conditions. Three-year-old bilinguals successfully recognized the word presented in the single-language context, but not the word presented in the mixed-language context. These results suggest a negative impact of language mixing on the learning of novel words that come after the mixed input.

Our motivation to conduct this study was that we expected that language mixing during the learning phase might impair children's ability to orient towards the labeled novel object. We thought that the mixing of the familiar word would cause a processing delay that would make it hard for the child to continue processing the rest of the sentence. Indeed, previous work has demonstrated that both children and adults experience a processing cost for language mixing (Byers-Heinlein et al., 2017, Grainger & Beauvillain, 1988; Meuter & Allport, 1999; Proverbio et al., 2004; Thomas & Allport, 2000). We expected that the mixing would have resulted in a difficulty first in understanding the familiar word, and in turn in identifying the novel object, as its identification relied on the processing of the mixed word. However, our analysis of looking behavior of the children during the learning phase did not support this prediction. We found that children looked at the labeled familiar target (e.g., dog/*chien*) whether they heard it in the single-language or mixed-language phrase. They gazed towards the novel target (e.g., teelo) in both conditions. This suggests that children were able to identify the labeled novel target even when it occurred after a mixed-input. Yet, despite looking towards the correct referent of the novel word in both conditions, they only appeared to associate the novel word with the referent in the single-language condition and not in the mixed-language condition. Again, this was very surprising as their performance in identifying the novel words during the learning phase was similar and therefore, they had a similar amount of time to encode the single-language and the mixed-language novel words.

Samuelson and colleagues (2008; 2017) make an important distinction between two phases in the word-learning process. The first phase is referent selection – determining what the likely referent of a novel word is. A second and separate phase is retention, which is linking the sound of the novel word to its meaning. A number of recent studies have shown that these are dissociable processes in word learning – sometimes children look towards the correct referent, for example in a mutual-exclusivity paradigm, but do not necessarily recognize that word later on test (Bion, Borovsky, & Fernald, 2013; Horst & Samuelson, 2008; O'Connell, Poulin-Dubois, Demke, & Guay, 2009). Our findings are consistent with this two-stage view of word learning. Children looked towards the labeled object in the mixed condition, but did not appear to associate the novel object and its label. The question remains as to why they made this association in the single-language condition, but not in the mixed-language condition.

One factor may have been that our word learning task was a cognitively demanding one. In our language mixing condition, children had to activate a language and inhibit the other as they processed speech signal in real-time. They had to recognize the familiar word, retrieve stored information about it and locate its referent on screen. They had to use grammatical cues to infer the location of the novel word's referent on screen and encode its visual properties. Finally, they needed make the association between the novel word and its referent, and perhaps identify the language of the novel word in order to store it as an English versus a French word. The resource limitation hypothesis posits that children have limited cognitive resources to devote to the task of word learning (Fennell & Werker, 2003; Stager & Werker, 1997). This hypothesis has mostly been considered in the context of minimal pair word learning in younger children, where children might ignore some challenging phonetic information when learning new words. However, it is possible to consider this hypothesis more broadly. Language mixing might be cognitively challenging, and in conjunction with the other challenges of our task, could have led to difficulty learning in the mixed-language condition.

One contributor to this difficulty is that children had the task of learning two words in the same experimental setting. Some studies have shown that children sometimes only learn one word when faced with a challenging word learning situation. For example, da Estrela & Byers-Heinlein (2016) investigated foreign word learning in 14-month-olds. In an easier condition where they were taught one native and one foreign-language word, children were able to learn both words. However, in a more challenging condition where they were taught two foreign-language words, they only learned one of the two words – in this case the first word that was heard during the study. This shows that although infants had the ability to learn more than one word in the same experimental setting, the level of difficulty of the task had an impact on that capacity. However, it is important to point out that children in our study, 3-year-olds, were much older than the 14-month-old infants tested in da Estrela & Byers-Heinlein's study. Some experiments that are arguably as challenging as ours have demonstrated successful learning of multiple words at this age (Wilkinson & Mazzitelli, 2003). Moreover, the successful learning of two novel words in an experimental setting has been demonstrated in infants as young as 12 months (MacKenzie, Graham, & Curtin, 2012). Thus, it is likely that in a less challenging experimental paradigm – perhaps without language mixing – children could have learned two words.

Another challenge of our task was that there were multiple objects onscreen during the learning phase – two familiar and two novel. Some studies have suggested that the presence of multiple objects can make word learning challenging. For example, Horst & Samuelson (2008) presented 24-month-old monolingual children with three objects: two familiar objects (e.g. a car and a cow) and one novel (e.g. a splicket). They instructed children to "Look at the splicke*t*! Which one is the splicket?" Because children knew the two other familiar objects, they could infer which object was being labeled by using mutual exclusivity. Children were very good at identifying the novel object as the referent of the novel word (i.e., referent selection), yet when tested they did not appear to retain this link (i.e., retention). Only when provided additional cues that heightened the novel object's salience, such as ostensive naming of the novel object, did infants retain its label. Authors suggested that although the familiar objects helped the children identify the novel object, they were also competing as possible referents for the novel word. According to this hypothesis, learning a novel word in our study would have been even harder, as there were three other potential competitors in each trial: the familiar target (e.g., dog), the familiar distractor (e.g., bunny), and the novel distractor (e.g., walem). In the event of such a difficult task, it is possible that our three-year-olds were only able to learn one word of the two novel words presented in the task, the easiest one, which in this case was the one that occurred in single-language trials.

Finally, it is important to note that many word learning tasks provide children with clear and unambiguous cues to the meaning of the word. For example, in most word-learning tasks only one object is present when a novel label is heard (Baldwin et al., 1996; da Estrela & Byers-Heinlein, 2016), or there are ostensive cues such as pointing or eye gaze indicating the relevant referent (Baldwin, 1993; Baldwin et al., 1996). However, our task required children to infer the meaning of the novel word, which again, is potentially challenging for the developing language learner. When children heard "Look! Do you see the dog on the teelo?", they had to infer that the teelo was the object underneath the dog – an additional processing step that might have made the task especially difficult. Our study is not the first that required children to make an inference as part of the word learning process (Bion et al., 2013; Horst & Samuelson, 2008; Goodman et al., 1998; Carey & Bartlett, 1978). In some of these previous studies, children could rely on semantic category information to determine the referent of the novel word. For example, in a study by Goodman et al., (1998), when hearing the sentence "Mommy feeds the ferret", children were presented with four novel objects that were clearly of different semantic categories (i.e., there was only one animal), which guided their decision. In other studies, only a single novel object was present during word learning (Horst & Samuelson, 2008). Our design did not have either of these features: children saw two novel objects that were of the same semantic category, which were both onscreen on each trial. Altogether, these factors might have made especially difficult to infer the meaning of the novel noun, and thus made our study especially challenging for word-learning.

While it is clear that our task was a challenging one for several reasons, the question still remains as to why children's cognitive resources might have gone towards associating the novel word and novel object in the single-language condition, and not in the mixed-language condition. Aside from the mixing of the familiar word, the tasks were equally hard in terms of number of objects to be learned, the ability of associative information, competition with objects on the screen, and inference difficulty for both novel words. Yet, children only learned the novel word in the single language sentence. Thus, our results demonstrate that language mixing poses a challenge for word learning, but our previous discussion does not resolve the question of why. In particular, why were children able to select the correct referent in the mixed-language condition, but not able to encode the link between the new word and the object?

One possibility is that language mixing does not offer the optimal learning opportunity for children, and thus they either implicitly or explicitly may choose not to encode a novel word that occurs in a mixed-language sentence. There is evidence from other studies that toddlers are selective word learners. For example, they prefer words coming from reliable over unreliable speakers (Brooker & Poulin-Dubois, 2013). It is possible that a mixed-language sentence is in some sense "unreliable", as it does not provide cues reliable enough for the child to know what to do with the novel word, therefore affecting their choice or ability to encode it. Some theories of bilingual language acquisition posit that even young bilingual learners encode the language of a word (Byers-Heinlein, 2014; Curtin, Byers-Heinlein, & Werker, 2011). In situations of language mixing, the language of a word is less clear, as the preceding sentence has words from both languages. Although our target novel word did have clear phonological characteristics of one language or the other (e.g., words were pronounced in either an English-like or a French-like way), these might have been insufficient. An interesting test of this possibility would be to teach children words in language-mixed contexts that are simpler than the one we used. For example, rather than having two novel and two familiar objects present on the screen as in the present study, there could either be only one novel-object pair (e.g., a dog on a teelo, no distractor), or only the novel object itself onscreen (e.g., only the teelo). If indeed the difficulty comes from not knowing where to store the novel word, we would predict that even in simpler referential contexts, children would nonetheless avoid learning a novel word that is presented in a mixed-language sentence.

Another possibility is that our analysis was not sensitive enough to pick up processing difficulties associated with hearing the mixed-language sentence. During the learning phase, we measured children's looking to the familiar and novel targets collapsed across a two-second time window, and in this window children looked at the targets similarly on the single-language and the mixed-language trials. If anything, children looked more to the targets in the mixed-language condition than in the single-language condition, although this difference was not statistically robust. A more fine-grained time course analysis could reveal subtler processing challenges for language mixing that we did not detect. Moreover, other studies have detected the cognitive challenges of language mixing using pupil dilation measures, where pupil size was shown to increase when hearing mixed-language sentences (Byers-Heinlein et al., 2017). It would be interesting to investigate children's pupillary response to our stimuli. If there was increased processing load in the mixed-language condition, children may not have had enough cognitive resources left over to encode the relationship between the novel word and the labeled object, despite looking correctly at it. This would be consistent with other studies showing a dissociation between referent selection and retention in cognitively challenging word learning tasks (Horst & Samuelson, 2008).

General Discussion

The goal of this research was to understand how language mixing affects word comprehension and learning in young bilinguals. More precisely, we were interested in knowing if the processing cost of language mixing (Byers-Heinlein et al., 2017; Meuter & Allport, 1999; Proverbio et al., 2004; Thomas & Allport, 2000) extends to the words that follow the mixed input. We tested French-English bilingual three-year-olds in two studies. One study tested them on their comprehension of a target word that occurred either in a single-language sentence (e.g., "Look! Can you find the pretty cow?"), or a mixed-language sentence where the mixing occurred at a prenominal adjective (e.g., "Look! Can you find *la jolie* cow?") The other study tested their learning of a novel word that was either taught in a single-language sentence (e.g., "Look! Do you see the dog on the teelo?"), or in a mixed-language sentence (e.g., "Look! Do you see the *chien* on the walem?"). Based on previous research reporting a processing cost of language mixing (Byers-Heinlein et al., 2017) we predicted that children's comprehension of familiar words (Study 1) and learning of novel words (Study 2) would be challenged by the mixed-input that preceded them.

Results from the comprehension study (Study 1) revealed no difference in looking at the familiar target between the single-language trials and the mixed-language trials. Contrary to predictions, this suggested that language mixing did not affect the comprehension of the familiar word that followed it. Indeed, based on previous studies reporting a cost of language mixing with infants (Byers-Heinlein et al., 2017) and with adults (Meuter & Allport, 1999; Proverbio et al., 2004; Thomas & Allport, 2000), we were expecting children to show difficulty in recognizing a familiar word that followed a mixed-input (e.g., “Look! Can you find *la jolie* cow?”), compared to a familiar word that was embedded in a single-language sentence (e.g., “Look! Can you find the pretty cow?”). A possible explanation is that the cost of mixing a target label on the comprehension of that label (e.g., “Look at the *chien*!” instead of “Look at the dog!”) previously found (Byers-Heinlein et al., 2017) does not affect the rest of the sentence. Unlike the comprehension of mixed words, comprehension of words that follow a mixed-input is not affected by language mixing. A second possible explanation is that mixed-language adjectives are less challenging to process than mixed-language nouns, which have more often been used in studies of language mixing. A final possible explanation is that there was no cost of mixing because the word that was mixed gave no information necessary to the identification of the familiar word that followed. Indeed, the mixed-input in our study consisted of a prenominal adjective and its determiner (e.g., the pretty/*la jolie*) that did not give any information that could help distinguish between the target and the distractor (e.g., a cow and a frog). This raised the question of what type of language mixing affects comprehension of familiar words. Would we have found different results had the mixing involved a word necessary for the identification of the referent? Results from Study 2 allowed us to test this hypothesis, while also investigating whether language mixing can affect word learning.

A key aspect of Study 2 was that the comprehension of the familiar noun preceding the novel word was necessary for children to identify the referent of the novel word (e.g., "Look! Do you see the dog on the teelo?"). We predicted that language mixing would affect processing of the familiar word (e.g., dog) that gave the necessary information for locating the novel object on the screen (e.g., teelo). This would in turn affect children's looking at the novel object. The results indicated that children successfully learned the word presented in the single-language sentence but not in the mixed-language sentence. However, while our prediction with regards to children's ability to learn in each situation was correct, we did not find support for original reasoning for why this would be the case. Contrary to our expectations, children did not look more at the novel target on single-language trials than on the mixed-language trials in the learning phase. This suggests that language mixing did not prevent children from identifying the correct referent for a novel word that followed language mixing. Thus, the learning phase of Study 2 replicated the finding from Study 1 that comprehension of words, familiar or novel, which follow language mixing was not affected by this language mixing. Further, this lack of effect persisted whether the mixed-word was necessary to the processing of the sentence (Study 2) or not (Study 1). However, results from our learning study (Study 2) revealed that language mixing made word learning more challenging, which was particularly surprising given that our analysis of the learning phase indicated that children were equally able to identify the referent of the novel label in both conditions.

These results suggest that children had enough time to encode the novel words in both conditions. The question remains: why were children able to learn the single-language novel word but not the mixed-language novel word? Based on the resource limitation hypothesis (Fennell & Werker, 2003; Stager & Werker, 1997), it is possible that our word learning task was so challenging that all of children's cognitive resources went into processing and encoding the easiest of the two words, which was the single-language novel word. Nonetheless, the single- and mixed-language novel words were both taught in the same challenging experimental task, and children were able to learn the single-language novel word, suggesting that the difficulty of our inferential learning task alone cannot explain our results. Another possible explanation is that children did not encode the novel word that followed the mixed-input because the context was not optimal for learning. For example, although our target novel words had clear phonological characteristics of one language or the other (e.g., words were pronounced in either an English-like or a French-like way), it is possible that those phonological cues were not enough to determine the language of the novel word. Further, as the rest of the sentence had elements from both languages, it did not provide any context for children to determine the language of the novel word. It is possible that because they had no reliable cues to determine the language of the novel word (Byers-Heinlein, 2014; Curtin et al., 2011), children did not know where to store it. In sum, our results provide clear evidence that word learning is more challenging in the context of language mixing, while the explanation for this remains unclear.

Altogether, results from these two studies contribute to a more nuanced view of how language mixing affects children's language acquisition. Previous research by our lab has pointed to the challenges of language mixing for language acquisition, whether by slowing down recognition of familiar words (Byers-Heinlein et al., 2017), or by predicting lower vocabulary size (Byers-Heinlein, 2013). However, Bail et al., (2015) found no relation between language mixing between sentences and vocabulary size, and a positive relation between language mixing within a sentence and vocabulary size. These different results might be because different types of language mixing affect children's language development in different ways, as demonstrated in our results. It therefore becomes important to identify which language mixing practices are a challenge to language acquisition compared to those that do not impact language acquisition.

Decades of research in the field of linguistics has demonstrated that language mixing does not occur randomly, but instead mixes occur at specific rule-governed locations (Boumans, 1998; Myers-Scotton, 1997; Poplack, 2001). For example, when two languages have different word orders, mixing is only possible at specific locations in the sentence where the word order between the two languages is aligned (Poplack, 2001). It is possible that due to their specific grammatical constraints, some language pairs authorize types of language mixing that are particularly challenging for acquisition, while other language pairs might be more resilient to the impacts of language mixing due to their inner structural constraints. This would be an important factor to take into account when comparing correlational results between language mixing and language acquisition. Further, as different parental and cultural practices differ across bilingual communities, this might predict different real-life effects of language mixing practice on language acquisition.

An important question remains: why do some types of language mixing have a stronger impact on word processing than others? What can explain the difference between the challenging effects of language mixing on the comprehension of a target noun (Byers-Heinlein et al., 2017) and the lack of effect on the comprehension of a target noun that occurs after a mixed-language adjective (Study 1)? A first possible explanation might be that some parts of speech are more heavily impacted than others by language mixing. Take the example of processing a noun vs. an adjective. In Study 1, we found no effects of mixing a prenominal adjective on comprehension of a noun that occurred later in the sentence (e.g., the pretty/*la jolie*). Previous research by Byers-Heinlein et al., (2017) found that comprehension of a mixed noun was less accurate than comprehension of a noun that was not mixed (e.g., dog/*chien*). These results could suggest that language mixing of a noun is more challenging than language mixing of an adjective. However, we did not find evidence for processing difficulty for the mixed-language noun in Study 2, which is inconsistent with this explanation.

Another possible explanation for these results might be that the demands of our experimental designs affected the mixing of a noun more than it affected the mixing of the adjective. Indeed, while previous research investigated the comprehension of the mixed noun itself (Byers-Heinlein et al., 2017), Study 1 did not directly assess the comprehension of the mixed adjective. Because children were instructed to look at a target object (a noun) it is possible that the mixed adjectives in our study did not require as much processing as would have required a mixed-language target noun. For example, in Byers-Heinlein et al., (2017.), when hearing "Look at the *chien*!", children had to: 1) process the mixed speech (*chien*), 2) retrieve the concept of dog, and 3) determine which object it referred to on the screen. However, when hearing the mixed adjective in Study 1 ("Look! Can you find *la jolie* cow?"), they were not required to find a referent for the adjective "the pretty/*la jolie*" on screen. Therefore, processing a mixed adjective in Study 1 might have involved one less processing step than identifying the target noun on screen in Byers-Heinlein et al., (2017). Further, because children in Study 1 were instructed to look at the target noun (e.g., "Look! Can you find *la jolie* cow?"), it is possible that all their cognitive resources went into processing the non-mixed target noun "cow", skipping over the mixed-adjective "*la jolie*".

The possibility that the demands of the experimental designs affected the mixing of nouns more than the mixing of adjectives could be tested by using adjectives that are imageable on screen and that would require children to process them in order to identify the correct target noun. For example, a future study could present children with two cows on the screen, a small one and a big one, while hearing an auditory stimulus similar to the one we used in Study 1 in a single-language sentence "Look! Can you find the small cow?", or in a mixed-language sentence "Look! Can you find *la petite* cow?" In this paradigm, children would be forced to process the adjective in order to identify the target object. If in this case mixed-language trials are more challenging than single-language trials, it would mean that it was indeed our experimental design that was the cause of the difference found in the effects of mixing a noun vs. the mixing of an adjective. However, if still no difference was found between the single- and mixed-language trials, it would suggest that the mixing of prenominal adjectives is less challenging to process for bilingual children than the mixing of a noun.

A second explanation to why some types of language mixing might be more detrimental than others relates to the location of the mixing. It would be possible that language mixing affects bilingual children's comprehension of words that occur in the end of a sentence more than words that occur in the middle of the sentence. In Study 1, we had predicted that mixing an adjective in the middle of a sentence (e.g., "Look! Can you find *la jolie* cow?) would affect the processing of that adjective ("*la jolie*"), and that it would cause a delay that would in turn affect the processing of the rest of the sentence ("cow"). However, we found that comprehension of the target noun that occurred in the end was not affected by the mixing. It is possible that the nature of infant-directed speech causes expectations in children that were not violated by language mixing in the middle of a sentence. In infant- and child-directed speech, important words are often placed in the end of a sentence (Fernald & Mazzie, 1991). Further, familiar sentences facilitate word recognition by preparing children's attention to be focused on a target word located at the end of the sentence (Fernald & Hurtado, 2006). It is possible that because important information usually happens in the end of a sentence in infant-directed speech, children are less affected by a processing difficulty (e.g., language mixing) that occurs in the middle of a sentence because they focus on the target word at the end. However, this explanation would need to be reconciled with our finding in Study 2 that mid-sentence language mixing did affect the learning of a word that occurred at the end of a sentence.

Some limitations of this study need to be addressed in order to answer some remaining questions. A first limitation concerns the measures used to assess word processing. In both studies, we measured children's looking to the familiar (Study 1 and Study 2) and novel targets (Study 2) collapsed across a two-second time window. We then compared children's looking times across conditions and found no difference that would account for comprehension of one condition being harder than the other. However, a more fine-grained time course analysis could reveal subtler processing challenges for language mixing that we did not detect. Moreover, other studies have shown pupil size to increase when hearing mixed-language sentences, suggesting increased cognitive challenge compared to the single-language trials (Byers-Heinlein et al., 2017). It would therefore be interesting to investigate children's pupillary response to our stimuli in case they reveal a subtler processing cost that we were not able to find with our current measures.

A second limitation concerning the age of our participants makes it challenging to directly compare our results with those of previous research (Byers-Heinlein et al., 2017). Indeed, our bilinguals were older than those tested by Byers-Heinlein and colleagues (2017) in their comprehension study, in which language mixing was found to affect speed and accuracy of looking to the familiar target in 20-months-old bilinguals. It is possible that the age difference played a role in our three-year-olds' capacity to correctly recognize the familiar target in both the single- and mixed-language trials. Like many other studies where children developed proficiency with age (Byers-Heinlein et al., 2013; Fennell et al., 2007; Fernald et al., 1998; Fernald et al., 2006), it is possible that our bilinguals' capacity to efficiently process words that occur after language mixing developed with time. It would therefore be interesting to test 20-month-old children in the same paradigm as our Study 1 to see how their results compare to bilingual three-year-olds. However, it should be noted that Byers-Heinlein et al. reported similar effects of language mixing for bilingual adults as for the 20-month-old bilingual infants, suggesting that the effects of language mixing might be continuous across the lifespan.

A third limitation concerns the question of ecological validity. How often are kids taught a novel word by having to infer its meaning? Although children can learn in a non-ostensive context (Bion et al., 2013; Tomasello, Strosberg, & Akhtar, 1996; Horst & Samuelson, 2008; Goodman et al., 1998; Carey & Bartlett, 1978), it remains unclear how often this occurs in their everyday environment, particularly in conjunction with language mixing. Nonetheless, identifying what specific language mixing practices are challenging, even if they do not occur frequently in children's everyday language environment, remains important as it might lead to a better understanding of how languages are monitored by young bilinguals, and thus lead to improved theories of the bilingual mind.

In sum, we tested 3-year-old bilinguals to assess the effects of language mixing in the middle of a sentence on the processing of the rest of the sentence. In Study 1, children were tested on their comprehension of a noun that occurred either in a single-language sentence (e.g., "Look! Can you find the pretty cow?"), or following a mixed adjective (e.g., "Look! Can you find *la jolie* cow?"). We found that language mixing had no effect on the comprehension of a noun that followed it. In Study 2, children were taught two words, one in a single-language sentence (e.g., “Look! Do you see the dog on the teelo?”), and one in a mixed-language sentence (e.g., “Look! Do you see the *chien* on the walem?). We found that although children identified the novel target on both single- and mixed- language learning trials, at test we only found evidence that children learned the novel word that was taught in single-language trials, and not the word that was taught in mixed-language trials. This suggests that language mixing may interfere with learning of words that follow.

Results from this thesis are important because although bilingual children are regularly exposed to language mixing, studies on the topic are limited and have relied mostly on parental report (Bail et al., 2015; Byers-Heinlein, 2013). Only one other published study directly tested the effects of language mixing on toddlers’ real-time comprehension (Byers-Heinlein et al., 2017). Ours is the first to directly test toddlers’ real-time comprehension of words that follow mixed input, and is the first study to test the effect of language mixing on word learning. Our results contribute greatly to the scarce research in the field by giving a more nuanced view of the effects of language mixing on language acquisition, leading to the important question of what type of language mixing has the largest effects on language development in young bilinguals. Given evidence that word processing in monolingual toddlers predicts language and cognitive skills at 8 years old (Marchman & Fernald, 2008), it is essential to study what parental practices are the most beneficial to an optimal bilingual language development. This will in turn lead to improved theories of bilingual language acquisition.

References

Bail, A., Morini, G., & Newman, R. S. (2015). Look at the gato! Code-switching in speech to toddlers. *Journal of Child Language*, *42*(5), 1073–1101.

Baldwin, D. A. (1993). Infants' ability to consult the speaker for clues to word reference. *Journal of Child Language*, *20*(2), 395–418.

Baldwin, D. A., Markman, E. M., Bill, B., Desjardins, R. N., Irwin, J. M., & Tidball, G. (1996). Infants' reliance on a social criterion for establishing word-object relations. *Child Development*, *67*(6), 3135–3153.

Bion, R. A., Borovsky, A., & Fernald, A. (2013). Fast mapping, slow learning: Disambiguation of novel word–object mappings in relation to vocabulary learning at 18, 24, and 30 months. *Cognition*, *126*(1), 39–53.

Bergelson, E., & Swingley, D. (2012). At 6–9 months, human infants know the meanings of many common nouns. *Proceedings of the National Academy of Sciences*, *109*(9), 3253–3258.

Bertoncini, J., & Mehler, J. (1981). Syllables as units in infant speech perception. *Infant Behavior and Development*, *4*, 247–260.

Boudreault, M. C., Cabirol, É. A., Trudeau, N., Poulin-Dubois, D., & Sutton, A. (2007). Les inventaires MacArthur du développement de la communication: Validité et données normatives préliminaires. *Revue canadienne d'orthophonie et d'audiologie*, *31*(1), 27–37.

Boumans, L. P. C. (1998). *The syntax of code-switching: Analysing Moroccan Arabic/Dutch conversation*. Tilburg: Tilburg University Press.

Brooker, I., & Poulin-Dubois, D. (2013). Is a bird an apple? The effect of speaker labeling accuracy on infants' word learning, imitation, and helping behaviors. *Infancy*, *18*(s1).

Byers-Heinlein, K. (2013). Parental language mixing: Its measurement and the relation of mixed input to young bilingual children's vocabulary size. *Bilingualism: Language and Cognition*, *16*(1), 32–48.

Byers-Heinlein, K. (2014). Languages as categories: Reframing the "one language or two" question in early bilingual development. *Language Learning*, *64*(s2), 184–201.

Byers-Heinlein, K., Fennell, C. T., & Werker, J. F. (2013). The development of associative word learning in monolingual and bilingual infants. *Bilingualism: Language and Cognition*, *16*(1), 198–205.

Byers-Heinlein, K., Morin-Lessard, E., & Lew-Williams, C. (2017). Bilingual infants control their languages as they listen. *Proceedings of the National Academy of Sciences*, 201703220.

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.

Byers-Heinlein, K., & Werker, J. F. (2013). Lexicon structure and the disambiguation of novel words: Evidence from bilingual infants. *Cognition*, *128*(3), 407–416.

Carey, S., & Bartlett, E. (1978). Acquiring a single new word. *Proceedings of the Stanford Child Language Conference*, 15: 17–29.

Cole, R. A., & Jakimik, J. (1980). A model of speech perception. *Perception and Production of Fluent Speech*, 133–163.

Core, C., Hoff, E., Rumiche, R., & Señor, M. (2013). Total and conceptual vocabulary in Spanish–English bilinguals from 22 to 30 months: Implications for assessment. *Journal of Speech, Language, and Hearing Research*, *56*(5), 1637–1649.

Curtin, S., Byers-Heinlein, K., & Werker, J. F. (2011). Bilingual beginnings as a lens for theory development: PRIMIR in focus. *Journal of Phonetics*, *39*(4), 492–504.

DeAnda, S., Hendrickson, K., Zesiger, P., Poulin-Dubois, D., & Friend, M. (2017). Lexical access in the second year: a study of monolingual and bilingual vocabulary development. *Bilingualism: Language and Cognition*, 1-14.

Dornic, S. (1980). Language dominance, spare capacity and perceived effort in bilinguals. *Ergonomics*, *23*(4), 369–377.

Dunn, L. M., & Dunn, D. M. (2007). *PPVT-4: Peabody picture vocabulary test*. Pearson Assessments.

Dunn, L. M., Dunn, L. M., & Thériault-Whalen, C. M. (1993). Échelle de vocabulaire en images Peabody: série de planches.

da Estrela, C., & Byers-Heinlein, K. (2016). Vois-tu le kem? Do you see the bos? Foreign word learning at 14 months. *Infancy*, *21*(4), 505–521.

Fennell, C., & Byers-Heinlein, K. (2014). You sound like Mommy: Bilingual and monolingual infants learn words best from speakers typical of their language environments. *International Journal of Behavioral Development*, *38*(4), 309–316.

Fennell, C. T., Byers-Heinlein, K., & Werker, J. F. (2007). Using speech sounds to guide word learning: The case of bilingual infants. *Child development*, *78*(5), 1510–1525.

Fennell, C. T., & Werker, J. F. (2003). Early word learners' ability to access phonetic detail in well-known words. *Language and speech*, *46*(2-3), 245–264.

Fenson, L., Marchman, V. A., Thal, D. J., Dale, P. S., Reznick, J. S., & Bates, E. (2007). *MacArthur-Bates Communicative Development Inventories: User's Guide and Technical*

Manual - Second Edition. Baltimore: Brookes Publishing.

Fernald, A., & Hurtado, N. (2006). Names in frames: Infants interpret words in sentence frames faster than words in isolation. *Developmental Science*, *9*(3).

Fernald, A., & Mazzie, C. (1991). Prosody and focus in speech to infants and adults. *Developmental Psychology*, *27*(2), 209.

Fernald, A., Perfors, A., & Marchman, V. A. (2006). Picking up speed in understanding: Speech processing efficiency and vocabulary growth across the 2nd year. *Developmental Psychology*, *42*(1), 98.

Fernald, A., Pinto, J. P., Swingley, D., Weinbergy, A., & McRoberts, G. W. (1998). Rapid gains in speed of verbal processing by infants in the 2nd year. *Psychological Science*, *9*(3), 228–231.

Ganger, J., & Brent, M. R. (2004). Reexamining the vocabulary spurt. *Developmental Psychology*, *40*(4), 621.

Gleitman, L. R., & Gleitman, H. (1992). A picture is worth a thousand words, but that's the problem: The role of syntax in vocabulary acquisition. *Current Directions in Psychological Science*, *1*(1), 31-35.

Goodman, J. C., McDonough, L., & Brown, N. B. (1998). The role of semantic context and memory in the acquisition of novel nouns. *Child development*, *69*(5), 1330–1344.Goodz, N. S. (1989). Parental language mixing in bilingual families. *Infant Mental Health Journal*, *10*(1), 25-44.

Grainger, J., & Beauvillain, C. (1988). Associative priming in bilinguals: Some limits of interlingual facilitation effects. *Canadian Journal of Psychology/Revue canadienne de psychologie*, *42*(3), 261.

Grosjean, F. (1982). *Life with two languages: An introduction to bilingualism*. Harvard University Press.

Grosjean, F. (1985). The recognition of words after their acoustic offset: Evidence and implications. *Attention, Perception, & Psychophysics*, *38*(4), 299–310.

Halberda, J. (2003). The development of a word-learning strategy. *Cognition*, *87*(1), B23-B34.

Horst, J. S., & Samuelson, L. K. (2008). Fast mapping but poor retention by 24-month-old infants. *Infancy*, *13*(2), 128–157.

Holowka, S., Brosseau-Lapré, F., & Petitto, L. A. (2002). Semantic and conceptual knowledge underlying bilingual babies' first signs and words. *Language learning*, *52*(2), 205–262.

Houston-Price, C., Caloghiris, Z., & Raviglione, E. (2010). Language experience shapes the development of the mutual exclusivity bias. *Infancy*, *15*(2), 125–150.

Horst, J. S., & Samuelson, L. K. (2008). Fast mapping but poor retention by 24-month-old infants. *Infancy*, *13*(2), 128–157.

Hurtado, N., Marchman, V. A., & Fernald, A. (2007). Spoken word recognition by Latino children learning Spanish as their first language. *Journal of Child Language*, *34*(2), 227–249.

Johnson, E. K., & Jusczyk, P. W. (2001). Word segmentation by 8-month-olds: When speech cues count more than statistics. *Journal of Memory and Language*, *44*(4), 548–567.

Jusczyk, P. W. (1997). Finding and remembering words: Some beginnings by English-learning infants. *Current Directions in Psychological Science*, *6*(6), 170–174.

Jusczyk, P. W., Friederici, A. D., Wessels, J. M., Svenkerud, V. Y., & Jusczyk, A. M. (1993). Infants′ sensitivity to the sound patterns of native language words. *Journal of Memory and Language*, *32*(3), 402–420.

Kuhl, P. K., Stevens, E., Hayashi, A., Deguchi, T., Kiritani, S., & Iverson, P. (2006). Infants show a facilitation effect for native language phonetic perception between 6 and 12 months. *Developmental Science*, *9*(2).

Lany, J. (2017). Lexical-processing efficiency leverages novel word learning in infants and toddlers. *Developmental Science*.

Lanza, E. (1992). Can bilingual two-year-olds code-switch?. *Journal of child language*, *19*(3), 633-658.

Lanza, E. (1997). Language contact in bilingual two-year-olds and code-switching: Language encounters of a different kind?. *International Journal of Bilingualism*, *1*(2), 135-162.

Legacy, J., Zesiger, P., Friend, M, & Poulin-Dubois, D. (2016). Vocabulary size and speed of word recognition in very young French-English bilinguals: a longitudinal study. *Bilingualism: Language and Cognition*. 1-13.

Libertus, M. E., Odic, D., Feigenson, L., & Halberda, J. (2015). A Developmental Vocabulary Assessment for Parents (DVAP): Validating parental report of vocabulary size in 2-to 7-year-old children. *Journal of Cognition and Development*, *16*(3), 442–454.

MacKenzie, H., Curtin, S., & Graham, S. A. (2012). Class matters: 12-month-olds' word–object associations privilege content over function words. *Developmental Science*, *15*(6), 753–761.

Marchman, V. A., & Fernald, A. (2008). Speed of word recognition and vocabulary knowledge in infancy predict cognitive and language outcomes in later childhood. *Developmental science*, *11*(3).

Marchman, V. A., Fernald, A., & Hurtado, N. (2010). How vocabulary size in two languages relates to efficiency in spoken word recognition by young Spanish–English bilinguals. *Journal of Child Language*, *37*(4), 817–840.

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language, and Hearing Research*, *50*(4), 940–967.

Markman, E. M., & Wachtel, G. F. (1988). Children's use of mutual exclusivity to constrain the meanings of words. *Cognitive psychology*, *20*(2), 121–157.

Marslen-Wilson, W., & Zwitserlood, P. (1989). Accessing spoken words: The importance of word onsets. *Journal of Experimental Psychology: Human Perception and Performance*, *15*(3), 576.

Mattock, K., Polka, L., Rvachew, S., & Krehm, M. (2010). The first steps in word learning are easier when the shoes fit: Comparing monolingual and bilingual infants. *Developmental science*, *13*(1), 229–243.

Merriman, W. E., Bowman, L. L., & MacWhinney, B. (1989). The mutual exclusivity bias in children's word learning. *Monographs of the Society for Research in Child Development*, i–129.

Meuter, R. F., & Allport, A. (1999). Bilingual language switching in naming: Asymmetrical costs of language selection. *Journal of Memory and Language*, *40*(1), 25–40.

Myers-Scotton, C. (1997). *Duelling languages: Grammatical structure in codeswitching*. Oxford University Press.

Nazzi, T., Iakimova, G., Bertoncini, J., Frédonie, S., & Alcantara, C. (2006). Early segmentation of fluent speech by infants acquiring French: Emerging evidence for crosslinguistic differences. *Journal of Memory and Language*, *54*(3), 283–299.

O'Connell, L., Poulin-Dubois, D., Demke, T., & Guay, A. (2009). Can Infants Use a Nonhuman Agent's Gaze Direction to Establish Word–Object Relations? *Infancy*, *14*(4), 414-438.

Pearson, B. Z., Fernández, S. C., & Oller, D. K. (1993). Lexical development in bilingual infants and toddlers: Comparison to monolingual norms. *Language learning*, *43*(1), 93–120.

Polka, L., & Bohn, O. S. (1996). A cross-language comparison of vowel perception in English-learning and German-learning infants. *The Journal of the Acoustical Society of America*, *100*(1), 577–592.

Polka, L., & Werker, J. F. (1994). Developmental changes in perception of nonnative vowel contrasts. *Journal of Experimental Psychology: Human perception and performance*, *20*(2), 421.

Poplack, S. (2001). Code-switching (linguistic). *International encyclopedia of the social and behavioral sciences*, 2062–2065.

Proverbio, A. M., Leoni, G., & Zani, A. (2004). Language switching mechanisms in simultaneous interpreters: An ERP study. *Neuropsychologia*, *42*(12), 1636–1656.

Reznick, J. S., & Goldfield, B. A. (1992). Rapid change in lexical development in comprehension and production. *Developmental Psychology*, *28*(3), 406.

Samuelson, L. K., Kucker, S. C., & Spencer, J. P. (2017). Moving word learning to a novel space: A dynamic systems view of referent selection and retention. *Cognitive Science*, *41*(S1), 52–72.

Shukla, M., White, K. S., & Aslin, R. N. (2011). Prosody guides the rapid mapping of auditory word forms onto visual objects in 6-mo-old infants. *Proceedings of the National Academy of Sciences*, *108*(15), 6038-6043.

Stager, C. L., & Werker, J. F. (1997). Infants listen for more phonetic detail in speech perception than in word-learning tasks. *Nature*, *388*(6640), 381.

Swingley, D. (2012). The Looking-While-Listening Procedure. In E. Hoff (Ed.), *Research methods in child language: A practical guide* (pp. 29–42). Malden, MA: Wiley-Blackwell.

Thomas, M. S., & Allport, A. (2000). Language switching costs in bilingual visual word recognition. *Journal of Memory and Language*, *43*(1), 44–66.

Tomasello, M., Strosberg, R., & Akhtar, N. (1996). Eighteen-month-old children learn words in non-ostensive contexts. *Journal of Child Language*, *23*(1), 157–176.

Vouloumanos, A., & Werker, J. F. (2007). Listening to language at birth: Evidence for a bias for speech in neonates. *Developmental Science*, *10*(2), 159–164.

Werker, J. F., Cohen, L. B., Lloyd, V. L., Casasola, M., & Stager, C. L. (1998). Acquisition of word–object associations by 14-month-old infants. *Developmental Psychology*, *34*(6), 1289.

Werker, J. F., & Fennell, C. T. (2004). Listening to sounds versus listening to words: Early steps in word learning. In D. G. Hall & S. R. Waxman (Eds.) *Weaving a lexicon* (79–109). Cambridge, MA: MIT Press.

Werker, J. F., Fennell, C. T., Corcoran, K. M., & Stager, C. L. (2002). Infants' ability to learn phonetically similar words: Effects of age and vocabulary size. *Infancy*, *3*(1), 1–30.

Wilkinson, K. M., & Mazzitelli, K. (2003). The effect of 'missing'information on children's retention of fast-mapped labels. *Journal of Child Language*, *30*(1), 47–73.

Table 1

Children's language background information

Child's Dominant Language	Parent-reported English Proficiency (on 10)	Parent-reported French Proficiency (on 10)	English Age of Regular Exposure (months)	French Age of Regular Exposure (months)	DVAP words produced in English	DVAP words produced in French	Total DVAP words	Other Languages of Exposure
French	9	10	10	birth	57	44	101	-
English	10	8	birth	birth	82	44	126	-
French	8	10	12	birth	19	45	64	-
English	10	9	birth	10	74	51	125	-
French	10	10	birth	birth	86	88	174	-
English	10	10	birth	birth	86	74	160	-
French	8	8	birth	birth	46	52	98	Spanish, Portuguese
English	10	8	birth	6	96	55	151	Russian
French	8	10	18	birth	-	-	-	-
English	10	10	birth	birth	102	60	162	-
English	10	10	birth	birth	67	19	86	-
French	8	10	8	birth	32	102	134	-
English	10	10	birth	birth	177	131	308	-
French	7	9	9	birth	23	43	66	Arabic
English	10	8	birth	9	64	27	91	-
French	8	10	birth	birth	72	90	162	-
French	8	10	11	birth	36	52	88	-
English	10	7	birth	birth	95	43	138	Portuguese, Spanish
English	9	9	birth	12	37	2	39	-
French	8	10	9	birth	39	69	108	-

Table 2

Children's looking to object type by condition (Study 2)

Source	*df*	*SS*	*MS*	*F*	*p*
Trial type	1	.000	.000	1.04	.32
Familiarity	1	.87	.87	31.52	< .001 *
Target type	1	4.05	4.05	153.72	< .001 *
Trial type x Familiarity	1	.00	.00	.28	.60
Trial type x Target type	1	.12	.12	1.16	.29
Familiarity x Target type	1	.69	.69	29.09	< .001 *
Target type x Familiarity x Trial type	1	.03	.03	5.27	.03 *

*Note: * p < .05*

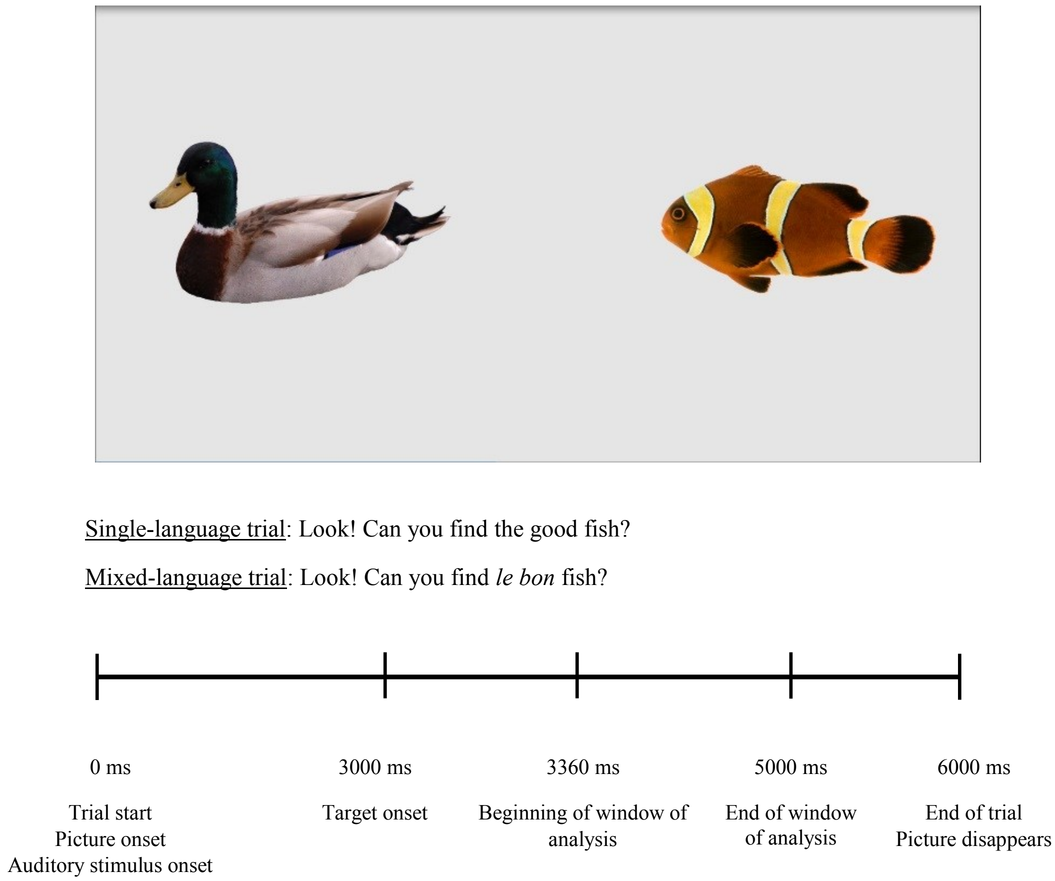

Figure 1. Schematic timeline of experimental procedure (Study 1). Note that diagram is for illustrative purposes and is not drawn to scale.

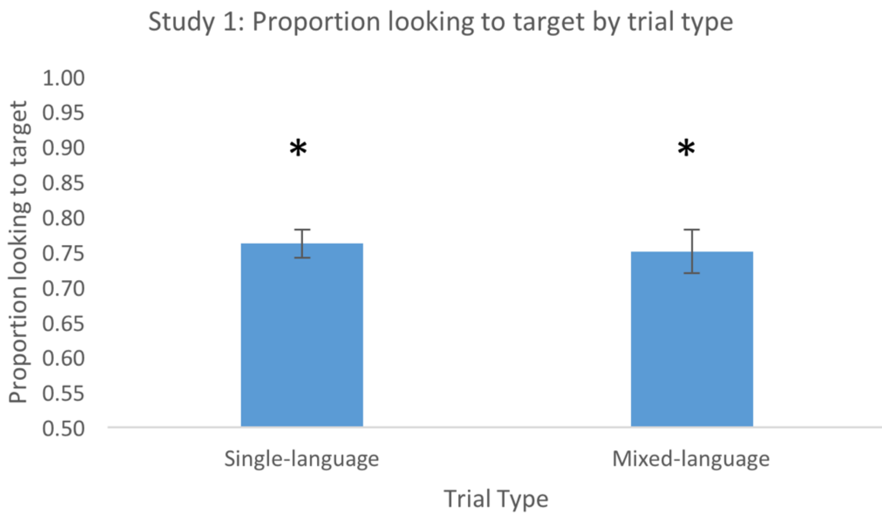

Figure 2. Proportion looking to familiar target by trial type (Study 1). Asterisks denote where children's proportion looking to target was significantly above chance (.50).

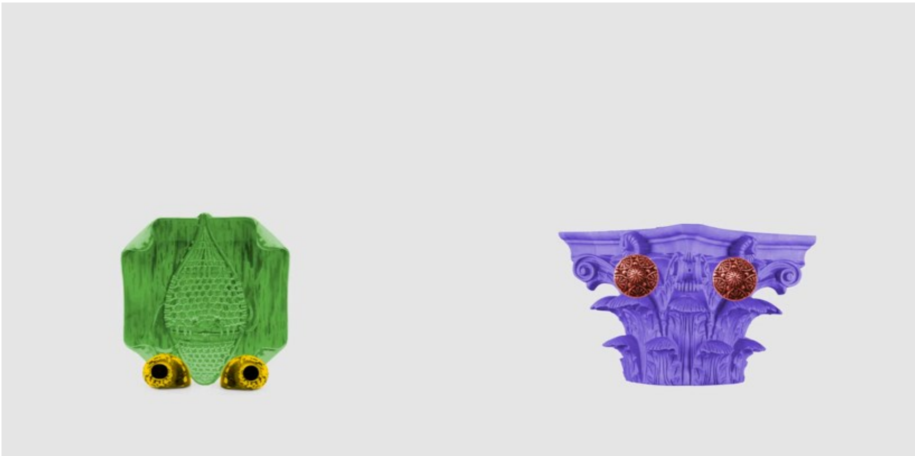

Figure 3. Novel objects used in Study 2. From left to right: walem and teelo

Learning phase

Single-language trial: Look! Do you see the pig on the **teelo**?

Mixed-language trial: Look! Do you see the *cochon* on the **teelo**?

0 ms	2000 ms	4500 ms	4860 ms	6500 ms	8500 ms
Trial start Picture onset	Auditory stimulus onset	Familiar label onset	Beginning of window of analysis	End of window of analysis	End of trial Picture disappears

Test Phase

Can you find the **teelo/walem**?

0 ms	2000 ms	3000 ms	3360 ms	5000 ms	6000 ms
Trial start Picture onset	Auditory stimulus onset	Target label onset	Beginning of window of analysis	End of window of analysis	End of trial Picture disappears

Figure 4. Schematic timeline of experimental procedure with a sample trial (Study 2). Note that diagram is for illustrative purposes and is not drawn to scale.

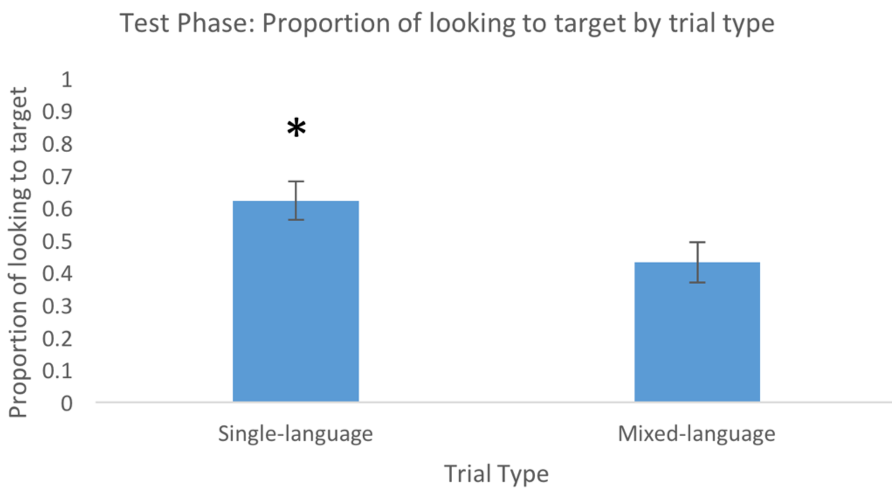

Figure 5. Proportion looking towards novel target by trial type during test phase of Study 2. Asterisks denote where children's looking to target was significantly above chance (.5).

Figure 6. Children's looking towards the four objects by trial type in the learning phase of Study 2.