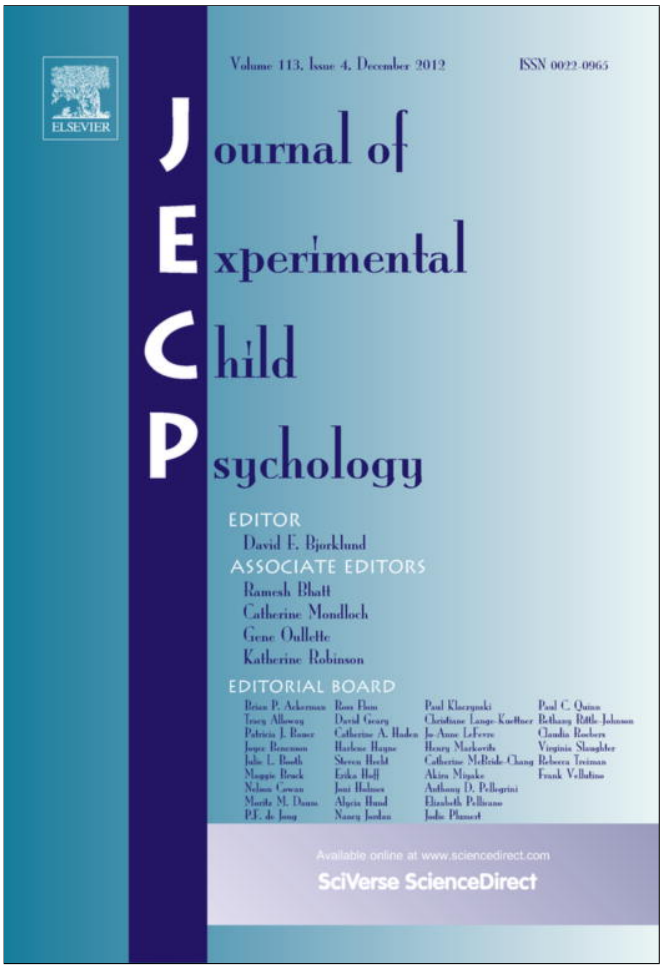

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Language nonselective lexical access in bilingual toddlers

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ABSTRACT

We examined how words from bilingual toddlers' second language (L2) primed recognition of related target words in their first language (L1). On critical trials, prime–target word pairs were either (a) phonologically related, with L2 primes overlapped phonologically with L1 target words [e.g., *slide* (L2 prime)–*Kleid* (L1 target, "dress")], or (b) phonologically related through translation, with L1 translations of L2 primes rhymed with the L1 target words [e.g., *leg* (L2 prime, L1 translation, "Bein")–*Stein* (L1 target, "stone"). Evidence of facilitated target recognition in the phonological priming condition suggests language nonselective access but not necessarily *lexical* access. However, a late interference effect on target recognition in the phonological priming through translation condition provides evidence for language nonselective lexical access: The L2 prime (*leg*) could influence L1 target recognition (*Stein*) in this condition only if both the L2 prime (*leg*) and its L1 translation ("Bein") were concurrently activated. In addition, age- and gender-matched monolingual toddler controls showed no difference between conditions, providing further evidence that the results with bilingual toddlers were driven by cross-language activation. The current study, therefore, presents the first-ever evidence of cross-talk between the two languages of bilinguals even as they begin to acquire fluency in their second language.

Introduction

Research exploring language processing in adult bilinguals has increased dramatically during recent years (Bialystok, 2010; Dupoux, Peperkamp, & Sebastián-Gallés, 2010; Wu & Thierry, 2010), but there is comparatively less work examining the development of phono-lexical processing in

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bilingual toddlers' language acquisition (but see Werker, Byers-Heinlein, & Fennell, 2009). Whereas some recent studies have investigated cognate processing and production in older bilingual children (e.g., Brenders, van Hell, & Dijkstra, 2011; Poarch & van Hell, 2012), the current study provides a novel examination of the language selectivity of lexical access (i.e., whether one or both languages of a bilingual are active during lexical processing) in bilingual toddlers. Our goal was to better understand the phono-lexical organization of the developing bilingual lexicon. Using a standard eye-tracking task, we examined how words from the second language (L2, English) of bilingual toddlers primed recognition of related words in their first language (L1, German). By manipulating the relationship between prime and target words, the current study clarifies the phono-lexical mechanisms underlying cross-language activation in bilingual toddlers' lexical processing.

Cross-language activation during adulthood

In a classic study of bilingual word recognition, Spivey and Marian (1999) presented Russian–English bilingual adults with groups of objects where the label for one of the objects presented (the target object) overlapped phonologically with the other-language label of a presented distracter object. For instance, the Russian label for the target object *marka* (''stamp'') overlapped phonologically with the English label for the presented distracter object, that is, a *marker* (''flomaster'' in Russian). The authors found that the presence of the other-language distracter interfered with target recognition; participants looked more toward the distracter object, *marker,* on hearing the similar-sounding Russian word (*marka*) relative to a phonologically unrelated distracter object (*lineka,* ''ruler''). This suggests that participants coactivated the English label for the depicted object (*marker*), which drove looks toward this object on hearing the target label (*marka*). This study was the first to show language nonselective access in bilingual auditory processing, that is, that bilinguals activate words from both languages in processing auditory stimuli (see also Ju & Luce, 2004; Lagrou, Hartsuiker, & Duyck, 2011; Marian, Spivey, & Hirsch-Pasek, 2003; Schulpen, Dijkstra, Schriefers, & Hasper, 2003; but see Fitzpatrick & Indefrey, 2009).

Phonological facilitation through translation: adapting to the priming methodology

One caveat to the studies reported above is that the vast majority of these manipulated the overt phonological similarity of the cross-linguistically related words, for example, *marka* (Russian, L1 prime, ''stamp'')–*marker* (English, L2 target, ''flomaster'' in Russian). When using overt phonological similarity to assess language nonselectivity, one could argue that any influence of the prime on target recognition is the result of purely acoustic overlap; that is, these findings need not necessarily imply the activation of *lexical* items from both languages of the bilingual in word recognition but may be driven by the activation of similar-sounding phonemes across languages.

More compelling yet are studies investigating *phonological priming through translation,* synthesizing both phonological and lexical processes. In such tests, participants are exposed to L2 primes whose L1 translations rhymed with L1 target words, for example, *leg* (''Bein'')–*Stein* (''stone''). The only way for the L2 prime (*leg*) to influence recognition of the L1 target word (*Stein*) is through coactivation of the L1 translation of the L2 prime (''Bein''); otherwise, *leg* and *Stein* do not overlap.

Costa, Miozzo, and Caramazza (1999, Experiment 5) presented the first investigation of phonological priming through translation. Catalan–Spanish bilinguals were instructed to name a picture in their L1, Catalan (*baldufa,* ''spinning top''), while hearing a distracter word (*pelea,* ''fight'') in their L2, Spanish. Crucially, if the Spanish distracter word (*pelea*) were to be translated to Catalan, its translation equivalent (*barella,* ''fight'') is phonologically similar to the Catalan label for the target image (*baldufa*). Despite the phonological similarity of the Catalan labels (*baldufa–barella*), the authors found no effect of phonological priming through translation; that is, participants were not faster to name the presented image in the context of the related Spanish distracter word (*pelea*) compared with an unrelated Spanish distracter word.

Using a different design, Duyck (2005) reported effects of *translation priming through phonology*. Dutch–English bilingual adults were visually presented with pseudohomophones, that is, nonwords such as *roap* whose phonological counterparts sounded similar to real English words (e.g., *rope,*

"touw" in Dutch). Participants showed faster recognition of "touw" (i.e., the Dutch translation equivalent of *rope*) when primed by English pseudohomophones such as *roap* compared with nonhomophonic pseudowords such as *joll.*

There are two very important differences between the designs of Costa et al. (1999) and Duyck (2005). On the one hand, Costa and colleagues tested phonological priming through translation, whereas Duyck tested translation priming through phonology. That is, in Costa and colleagues' study, participants needed to first translate the L2 prime word (*pelea*) to L1 (*barella*) before phonological overlap with the L1 target (*baldufa*) could influence their response. In Duyck's study, participants were first presented with a pseudoword prime (*roap*) that sounded similar to an L2 word (*rope*) before responding to the L1 translation (*touw,* "rope") of the L2 word. It might be relatively easy for phonology to first be activated and for that activation to spread to the lexical level, thereby resulting in a translation priming through phonology effect as found in Duyck's study. In contrast, more effort may be required for translations to be activated from their L2 entries and for that activation to spread to the phonological level, leading to no significant effects of phonological priming through translation in Costa and colleagues' study. If this is the case, the current study with toddlers should find no effect of priming when presenting an L2 prime that, when translated to L1, is phonologically similar to the L1 target (as tested in Costa et al., 1999).

On the other hand, Costa et al. (1999) employed a production task, where participants were instructed to name pictures, whereas Duyck (2005) employed a perception task, where participants were instructed to decide whether a presented string of letters was a real Dutch word or not. Might the differences in the results of Costa and colleagues and Duyck stem from differences in the selectivity of lexical access in production and perception tasks? If the differences in results were due to the differences in task alone, we would expect to find effects of phonological priming through translation in the word recognition task employed in the current study.

Language nonselective lexical access in bilingual development

Although there are no studies investigating language nonselectivity in bilingual toddlers, some studies have investigated cognate processing and production in older bilingual school-aged children. For instance, Brenders et al. (2011) showed faster processing of English–Dutch cognates in the children's L2 relative to noncognate control L2 words (see also Poarch & van Hell, 2012). Although the authors interpreted these findings as suggestive of language nonselective lexical access in school-aged bilingual children, such results may be specific to the processing of cognate words alone. For example, children may have more frequent exposure to cognate words (because they exist in both of their languages) compared with language-unique control words (Sherkina-Lieber, 2004). Therefore, although these findings suggest language nonselective access in bilingual school-aged children, the use of cognates may limit the generalizability of this conclusion.

Monolingual and bilingual phono-lexical processing during development

Looking at a younger age, we know that by 10 to 12 months, both monolingual and bilingual infants successfully discriminate speech sound contrasts that occur in their native language (Albareda-Castellot, Pons, & Sebastián Gallés, 2011; Burns, Yoshida, Hill, & Werker, 2007; Kuhl et al., 2006; Sundara, Polka, & Molnar, 2008; but see Bosch & Sebastián Gallés, 2003; Burns, Werker, & McVie, 2004). Similarly, both monolingual and bilingual infants succeed at learning minimally different word–object associations by at least 17 months of age (e.g., /bos/–/gos/) so long as the stimuli used to test bilinguals were produced by a bilingual speaker (Mattock, Polka, Rvachew, & Krehm, 2010; Werker, Fennell, Corcoran, & Stager, 2002; but see also Fennell, Byers-Heinlein, & Werker, 2007).

Nevertheless, when it comes to displaying sensitivity to small changes to the pronunciations of words, monolingual infants appear to detect small mispronunciations of words at a much earlier age, 12 months (Mani & Plunkett, 2010, see also Mani & Plunkett, 2007; Swingley & Aslin, 2002), compared with bilingual infants. Indeed, bilingual Spanish–Catalan infants display sensitivity to mispronunciations of Catalan words at only 24 months of age (Ramon-Casas, Swingley, Sebastián Gallés, & Bosch, 2009). This might, in turn, affect the degree to which bilingual toddlers display sensitivity to

phonological priming in the current study. The results of Mattock et al. (2010) suggest that bilingual infants are sensitive to the internal phonological structure of a word and might, therefore, display sensitivity to phonological priming to the same extent as monolingual toddlers. The results of Ramon-Casas et al. (2009) suggest that bilingual toddlers might not access the phonological detail associated with words in some tasks and might not display phonological priming effects to the same extent as monolingual toddlers at very young ages. With a view to outlining the established developmental milestones of phonological priming in monolingual toddlers, the next section provides a review of the literature on phonological priming in monolingual infants and adults.

Priming effects during development and adulthood in phono-lexical processing

In phonological priming tasks, participants are tested on their recognition of a word following exposure to a word that overlaps in phonological form with the target word to be recognized (e.g., *cat,* prime–*hat,* target). Tasks manipulating rhyme priming typically find improved recognition of a target word following exposure to a rhyming prime word (Allopenna, Magnuson, & Tanenhaus, 1998; Columbo, 1986; Norris, McQueen, & Cutler, 2002). Nevertheless, the adult literature reports inconsistencies in the direction of phonological priming effects across studies, with some studies reporting facilitation in target recognition in phonologically primed trials relative to unrelated trials and other studies reporting interference in target recognition (see Radeau, Morais, & Segui, 1995, for an extensive review of phonological priming studies showing opposing effects). These inconsistencies have been explained by implicating the level of processing involved, with facilitation effects (especially in rhyme-priming tasks) typically indexing prelexical phonological-level effects and interference effects indexing lexical-level activation of phonological competitors (Radeau et al., 1995; Slowiaczek & Hamburger, 1992).

A similar discussion is under way in studies examining phonological priming in young children (Mani & Plunkett, 2010; Mani & Plunkett, 2011). Mani and Plunkett (2011) argued that facilitatory phonological priming effects found in young infants' responding in phonological priming tasks index prelexical phonological-level processing; the phonemes shared by the target and prime are activated during presentation of the prime, thereby speeding recognition of the target. In contrast, it is suggested that the interference effects reported in older children index lexical-level competition between the words that sound similar to the target and the prime. In other words, toddlers, on hearing a familiar word prime, activate other words that sound similar to the heard word. These other words compete with the target for recognition, leading to reduced recognition.

Taken together, across the adult and infant literature, there appears to be symmetry in the processes underlying facilitatory and interference effects in phonological priming tasks, with facilitatory effects indexing prelexical phonological-level processes and interference effects suggesting lexical-level activation of competing words. These differences in the direction of priming effects can also be envisioned over time. The visual world paradigm, used often with adults, is well suited for revealing how syntactic (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995), semantic (Yee, Overton, & Thompson-Schill, 2009; Yee & Sedivy, 2006), and phonological (Allopenna et al., 1998) competitors are activated and resolved over time during spoken word recognition. Observation of this activation and its resolution is made possible by the temporal information that the visual word paradigm provides; instead of giving singular reaction time information, the eye-tracking data associated with the visual world paradigm supplies a window into competitor activation as it arises and is resolved. In the current study, we employed infant preferential looking that similarly supplies rich information about infant word processing and recognition as it unfolds.

Novelty of the current study

The current study extends previous research demonstrating language nonselective lexical access to bilingual toddlers. First, this study presents an investigation of cross-language priming effects in younger children than have been examined to date. By examining phono-lexical processing in bilingual toddlers, the current study compares previous monolingual and bilingual adult research with that of bilingual development. Second, we improve on previous studies by examining the processing of

auditorally presented noncognate words, thereby avoiding potential complications due to the special status of cognate words. Third, in contrast to the literature to date, we attempt to disambiguate phonological-level versus lexical-level effects in bilingual toddlers' word recognition. This was done by manipulating the relationship between the English prime words and the German target words across three conditions:

1. Phonological priming, where the English prime and German target overlapped phonologically across languages (*slide–Kleid,* "dress").[1]
2. Phonological priming through translation, where the German translation of the English prime (*leg,* "Bein") rhymed with the German target (*Stein,* "stone").
3. Unrelated, where prime and target words were not related phonologically, semantically, or in any translation form (*mouth–Buch,* "book").

In keeping with phonological priming effects in the monolingual literature to date, we predicted facilitation in target recognition in phonological priming trials compared with unrelated trials (Radeau et al., 1995; Slowiaczek & Hamburger, 1992). We argue that priming of overtly phonologically similar words across languages may be driven purely by phonological overlap and might not necessarily imply language nonselective *lexical* access. In the phonological priming through translation trials, given the absence of overt overlap between *leg* and *Stein,* a priming effect in this condition would provide strong evidence of language nonselective lexical access, that is, activation of both *leg* and "Bein." Concurrent activation of multiple lexical candidates typically leads to interference in target recognition (Mani & Plunkett, 2011; Swingley & Aslin, 2007), which would predict reduced target recognition in phonological priming through translation trials compared with unrelated trials.

Method

Participants

The participants were 20 toddlers, ranging in age from 21 to 43 months[2] (M = 31.30 months, SD = 6.44, Mdn = 31.00, 9 girls and 11 boys), recruited from a local bilingual preschool in central Germany. The average amount of time in preschool was 12.35 months (SD = 6.07). Of the total sample, 3 children were excluded from analyis due to their not hearing German at home (1) or not completing the experiment (2). The remaining 17 children heard German at home and heard German and English equally often in the day care facility. Of these toddlers, 4 also heard English at home, whereas 1 toddler heard Turkish at home. We considered German to be their L1 and English to be their L2.

Toddlers from this particular preschool were chosen because they received an equivalent amount of instruction in both English and German during their time at the preschool (6–8 h/day). This method of instruction, called an "enrichment program" (Rohde, 2001), provides an ideal setting for studying L2 learning because all children receive the same amount of daily L2 English exposure. Bilingual instruction is carefully managed by preschool teachers such that the teachers address the toddlers using one language consistently and never the other. This is styled after the "one parent, one language" theory (Bain & Yu, 1980; Ronjat, 1913). This principle is applied in many preschools (Genesee, 2010; Rohde, 2001) aside from the bilingual preschool of the current study. The purpose of the current study is not to evaluate the effectiveness of the "one parent, one language" theory. Neither do we make assumptions about whether these toddlers should be considered simultaneous or sequential bilinguals, leaving an exploration of this distinction to future research.

[1] Although the words tested in this condition do not rhyme, they overlap phonologically at least to the same extent as in previous adult studies of phonological priming across languages (see, e.g., Spivey & Marian, 1999). Thus, although there are differences in the vowels of the words across languages (and the extent to which they are rhotacized), the sounds in the overlapping words are similar across languages and should assimilate to each other perceptually in either language.

[2] It should be noted that the age range is considerably larger compared with those in typical IPL studies. However, ensuring that all of the toddlers experienced the same bilingual environment was viewed as a greater advantage than testing toddlers of a very similar age.

To ensure that any priming effects found in the bilingual toddlers are due to the manipulation of cross-language overlap, we also tested a group of monolingual toddlers on the same experiment. A total of 17 age- and gender-matched monolingual toddlers (age range = 21–43 months, *M* = 31.30, *SD* = 6.44, *Mdn* = 31.0, 9 girls and 8 boys) were recruited locally in the same area as the bilingual preschool.

Stimuli

We selected 12 English and 12 German nouns that were familiar to children by 18 months of age according to the British Communicative Development Inventory (OCDI; Hamilton, Plunkett, & Schafer, 2000) and its German equivalent, the Fragebogen zur Frühkindlichen Sprachentwicklung (FRAKIS; Szagun, Stumper, & Schramm, 2009), respectively. In addition, 12 images served as yoked distracters for each target image across conditions. The relationship between target–distracter pairs was controlled such that there was no phonological or semantic relationship between them. The English nouns served exclusively as prime words presented at the end of a carrier phrase (e.g., "I have a nose"). The German nouns served exclusively as targets presented in isolation (e.g., *Stein,* "stone"). Toddlers were tested in two blocks on the different prime and target–distracter pair combinations. Stimuli were chosen so that cohort size, neighborhood size, and frequency of the primes and targets were similar across the three conditions. Indeed, *t* tests indicated no differences in the cohort size, neighborhood size, and frequency of the primes and targets between the phonological priming and unrelated conditions or the phonological priming through translation and unrelated conditions (*ps* > .20). Table 1 presents a complete list of stimuli presented to children. Stimuli were recorded by a German–English bilingual female speaker using infant-directed speech. Prime words were recorded with a carrier phrase (e.g., "I saw a X," "I have a X," "I bought a X"), where the prime word always occurred at the end of the carrier phrase. Carrier phrases and prime words were always English. In addition, the target words, which were always German, were recorded in isolation. The target and distracter images chosen were computer images created from easily recognizable prototypical photographs of the target or distracter.

Procedure

Bilingual toddlers were tested in their preschool using an adaptation (Arias-Trejo & Plunkett, 2009) of the intermodal preferential looking paradigm (Golinkoff, Hirsch-Pasek, Cauley, & Gordon, 1987). Each toddler was tested individually in a room separated from the rest of the preschool. The toddler either sat alone or sat on the lap of a teacher. A large computer monitor placed 60 cm away from the participant displayed the target–distracter images. Target–distracter images measured 17.5 × 13 cm and appeared side by side on the screen. Two loudspeakers presented the auditory stimuli, one on either side of the computer monitor. A video camera centered above the computer monitor recorded digital video images of the child during the experiment. Monolingual toddlers were tested individually in a laboratory setting. Each toddler either sat alone or sat on the lap of a parent 60 cm away from a large television screen. Target–distracter images measured 27 × 20 cm and appeared side by side on the screen. Two loudspeakers situated above the television screen presented the auditory stimuli. Two video cameras centered above the television screen recorded digital images of the child during the experiment.

Experimental design

Children saw 24 trials across two blocks of 12 trials each. In each block of 12 trials, toddlers were presented with 3 phonological priming trials, 3 phonological priming through translation trials, and 6 unrelated trials, where the prime and target pairs were unrelated to one another semantically, phonologically, and in translation form. In the second block of 12 trials, toddlers were presented with the same stimuli in a different condition. That is, those target–distracter pairs that were presented in the phonological priming and phonological priming through translation conditions in the first block were now presented in the unrelated condition and vice versa. This ensured that each child heard the prime word and saw target–distracter pairs only once per block.

Each trial began with a priming phase, where the carrier phrase containing the prime word was played while toddlers were presented with a centrally located fixation cross. The onset of the carrier

Table 1
Summary of stimuli and their International Phonetic Alphabet transcriptions presented to children separated by condition: Phonological priming, phonological priming through translation, and unrelated.

Condition	Prime label		Target label/image		Distracter image	
	English	German translation	German	English translation	German	English
Phonological priming	Fire /faɪəˑ/	Feuer /fɔyɛʀ/	Eier /aɪɛʀ/	Eggs /ɛgz/	Uhr /u:ʀ/	Clock /klɑk/
	Door /dɔ:r/	Tür /ty:ʀ/	Ohr /o:ʀ/	Ear /i:əˑ/	Baum /baʊm/	Tree /tri:/
	Slide /slaɪd/	Rutsche /rʊtʃɛ/	Kleid /klaɪd/	Dress /drɛs/	Keks /ke:ks/	Cookie /kʊki:/
	Blue /blu:/	blau /blaʊ/	Kuh /ku:/	Cow /kaʊ/	Elefant /e:lɛfant/	Elephant /ɛləfənt/
	Dish /dɪʃ/	Teller /tɛlɛʀ/	Tisch /tɪʃ/	Table /teɪbəl/	Eimer /aɪmɛʀ/	Bucket /bʌkət/
	Moon /mu:n/	Mond /mo:nd/	Huhn /hu:n/	Chicken /tʃɪkən/	Schaf /ʃa:f/	Sheep /ʃi:p/
Phonological priming through translation	Nose /noʊz/	Nase /na:zɛ/	Hase /ha:zɛ/	Hare /hær/	Pferd /pfe:ʀd/	Horse /hors/
	Bottle /bʌtəl/	Flasche /flaʃɛ/	Tasche /taʃə/	Purse /pɜˑs/	Pflanze /pflantsɛ/	Plant /plænt/
	Soup /su:p/	Suppe /zʊpɛ/	Puppe /pʊpə/	Doll /dɑl/	Blume /blu:mɛ/	Flower /flɑʊwəˑ/
	Leg /lɛg/	Bein /baɪn/	Stein /ʃtaɪn/	Stone /stoʊn/	Mütze /mytsɛ/	Hat /hæt/
	Cloth /klɑθ/	Tuch /tu:x/	Buch /bu:x/	Book /bʊk/	Auge /augɛ/	Eye /aɪ/
	Mouth /maʊθ/	Mund /mʊnd/	Hund /hʊnd/	Dog /dɔg/	Schlüssel /ʃlysɛl/	Key /ki:/
Unrelated	Nose /noʊz/	Nase /na:zɛ/	Eier /aɪɛʀ/	Eggs /ɛgz/	Uhr /u:ʀ/	Clock /klɑk/
	Bottle /bʌtəl/	Flasche /flaʃɛ/	Ohr /o:ʀ/	Ear /i:əˑ/	Baum /baʊm/	Tree /tri:/
	Soup /su:p/	Suppe /zʊpɛ/	Kleid /klaɪd/	Dress /drɛs/	Keks /ke:ks/	Cookie /kʊki:/
	Leg /lɛg/	Bein /baɪn/	Kuh /ku:/	Cow /kaʊ/	Elefant /e:lɛfant/	Elephant /ɛləfənt/
	Moon /mu:n/	Mond /mo:nd/	Tisch /tɪʃ/	Table /teɪbəl/	Eimer /aɪmɛʀ/	Bucket /bʌkət/
	Slide /slaɪd/	Rutsche /rʊtʃɛ/	Huhn /hu:n/	Chicken /tʃɪkən/	Schaf /ʃa:f/	Sheep /ʃi:p/
	Door /dɔ:r/	Tür /ty:ʀ/	Hase /ha:zɛ/	Hare /hær/	Pferd /pfe:ʀd/	Horse /hors/
	Fire /faɪəˑ/	Feuer /fɔyɛʀ/	Tasche /taʃə/	Purse /pɜˑs/	Pflanze /pflantsɛ/	Plant /plænt/
	Dish /dɪʃ/	Teller /tɛlɛʀ/	Puppe /pʊpə/	Doll /dɑl/	Blume /blu:mɛ/	Flower /flɑʊwəˑ/
	Blue /blu:/	blau /blaʊ/	Stein /ʃtaɪn/	Stone /stoʊn/	Mütze /mytsɛ/	Hat /hæt/
	Mouth /maʊθ/	Mund /mʊnd/	Buch /bu:x/	Book /bʊk/	Auge /augɛ/	Eye /aɪ/
	Cloth /klɑθ/	Tuch /tu:x/	Hund /hʊnd/	Dog /dɔg/	Schlüssel /ʃlysɛl/	Key /ki:/

Note. For prime label and target label/image, the language the toddlers heard is given first except for the distracter image, which was never labeled.

phrase into the trial was timed such that the offset of the prime label was always at 1500 ms. Here, 1700 ms into the trial (i.e., 200 ms after the offset of the prime label), the child was presented with the target label, followed by the target and distracter images appearing on-screen at 1750 ms. The target and distracter images remained on-screen for 2000 ms, giving the trial a total duration of 3750 ms.

Across the two blocks and across participants, stimuli were counterbalanced such that primes appeared equally often in related (phonological priming and phonological priming through translation) and unrelated conditions. Similarly, target–distracter pairs appeared equally often in related and unrelated conditions across participants. Items were not repeated within blocks. Target side was randomized, with no bias toward the target appearing to the left or right of the screen. Order of presentation of trials within blocks was randomized, and blocks were counterbalanced across participants. Trials began only once children fixated the screen in front of them.

Analysis

The video images were coded offline to determine the direction of children's fixations during the experiment (every 40 ms). The coder was blind to the identity of the images and auditory stimuli during offline coding. A second skilled coder coded 15% of the participants, verifying a high percentage of coder agreement for both the bilingual ($r = .99$, $p < .0001$) and monolingual ($r = .99$, $p < .0001$) priming studies. Only eye movements initiating between 233 and 2000 ms after onset of the target word were analyzed. This ensured that only those eye movements that could reliably constitute a response to the auditory stimulus were considered (Canfield & Haith, 1991; Swingley & Aslin, 2007). As in previous work (Mani, Durrant, & Floccia, 2012; Mani & Plunkett, 2010, 2011), only those trials where toddlers fixated the target and distracter at least once during the experiment were included in the analysis. The coded video images provided a measure of the amount of time toddlers spent looking at the target (T) and distracter (D) during the postnaming phase, that is, after the target was labeled. The dependent variable in the analyses reported here is the proportion of time toddlers spent looking at the target [PTL = T / (T + D)] in this postnaming window (233–2000 ms posttarget word onset).

Naming study

On completing the priming study, the bilingual toddlers were tested on their recognition of both the English prime words and the German target words, whereas monolingual toddlers were tested on the German target words. Here, each trial began with the presentation of two familiar images side by side on a screen. One of these images, the target image, was either the image used for the German target in the priming study [e.g., the picture of the stone (*Stein*) presented to toddlers in the priming study] or, in the case of the bilingual toddlers, an appropriate image for the English prime label (e.g., a picture of a leg). The other image, the distracter image, was the yoked distracter image that was presented to children alongside the German targets in the priming study. At 2500 ms into the trial, children heard the label for the target image. We calculated the proportion of time that toddlers spent looking at the target image during the pre- and the postnaming phases of the trial. A significant increase in target looking after naming is considered an indication that children correctly associated the target image with its label.

Results

Naming study

Bilingual naming study

A repeated measures analysis of variance (ANOVA) with the factor naming (prenaming or postnaming) found a significant main effect of naming when children were tested on the English prime words, $F(1,18) = 5.03$, $p = .038$, $\eta_p^2 = .218$, and the German target words, $F(1,14) = 65.64$, $p < .001$, $\eta_p^2 = .82$. Children looked more toward the target during the postnaming phase (English: $M = .63$, $SD = .11$; German: $M = .70$, $SD = .08$) relative to the prenaming phase (English: $M = .58$, $SD = .09$; German:

M = .51, SD = .09) on hearing English prime words and German target words. We interpret this increase in target looking postnaming to signify that children were, on average, familiar with the English prime and German target words used in the main study.

Monolingual naming study

A repeated measures ANOVA with the factor naming (prenaming or postnaming) found a significant main effect of naming when children were tested on the German target words, $F(1,19) = 22.49$, $p < .001$, $\eta_p^2 = .54$. Target looking increased from prenaming ($M = .57$, $SD = .09$) to postnaming ($M = .73$, $SD = .10$) for German target words. We interpret this increase in target looking postnaming to signify that the monolingual children were, on average, familiar with the German target words used in the priming study.

Bilingual priming study

Preanalysis

A 2 (Testing Block) × 3 (Condition) repeated measures ANOVA revealed no main effect of testing block, $F(1,15) = 1.99$, $p = .17$, and no significant interaction between testing block and condition, $F(2,14) = 0.26$, $p = .77$. A repeated measures ANOVA with condition as a within-participants factor and age of the participants (range = 648–1307 days) as a covariate showed no significant interaction between age and condition, $F(2,14) = 0.53$, $p = .60$. A repeated measures ANOVA with condition as a within-participants factor and duration of L2 exposure [i.e., number of days since beginning English instruction ($M = 381.18$, $SD = 169.49$, range = 153–680) as a covariate] showed no significant interaction between duration of L2 exposure and condition, $F(2,14) = 0.47$, $p = .64$. Therefore, all analyses are carried out collapsed for testing block, age, and duration of L2 exposure.

Main analysis

Each child's looking times were aggregated by condition, creating a participant PTL mean for each of the three conditions. Fig. 1 plots the mean PTL in each of the three conditions presented to children. A repeated measures ANOVA with the factor condition (phonological priming: $M = .60$, $SD = .07$;

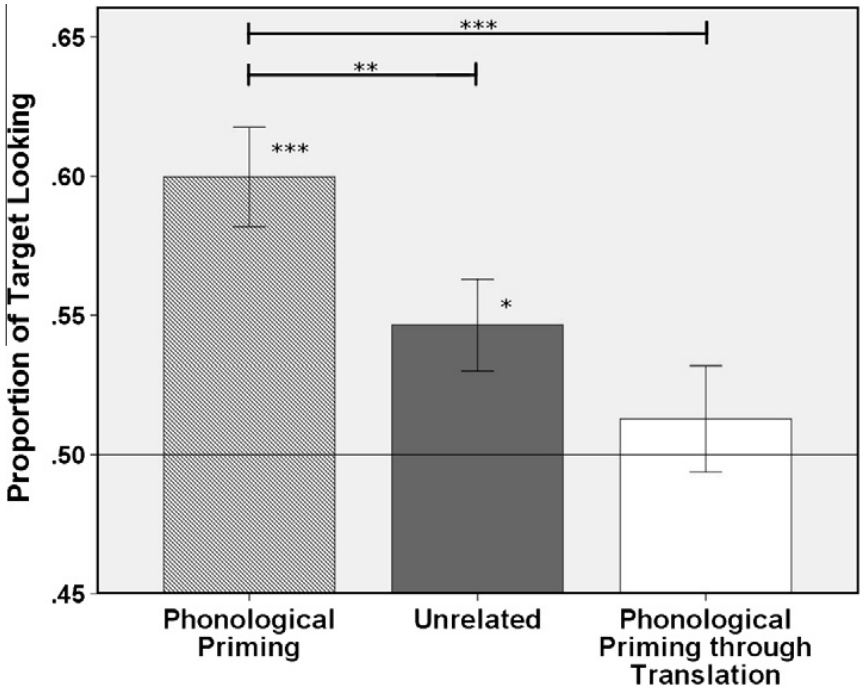

Fig. 1. Mean proportions of target looking in the phonological priming, phonological priming through translation, and unrelated conditions presented to children. Asterisks indicate significant differences between conditions and whether target looking was above chance (***$p < .001$; **$p < .01$; *$p < .05$). Error bars are ±1 standard error.

phonological priming through translation: $M = .51$, $SD = .08$; unrelated: $M = .55$, $SD = .07$) found a significant main effect of condition, $F(2,15) = 7.91$, $p = .005$, $\eta_p^2 = .51$. Separate pairwise analyses revealed significant differences between the phonological priming and unrelated conditions, $t(16) = 2.94$, $p = .01$, $d = 0.77$, and between the phonological priming and phonological priming through translation conditions, $t(16) = 3.94$, $p = .001$, $d = -0.47$. However, no significant difference was found between the phonological priming through translation and unrelated conditions, $t(16) = -1.64$, $p = .12$, $d = 0.47$. Target recognition was significantly greater than chance for both the phonological priming condition, $t(16) = 5.57$, $p < .0001$, $d = 0.93$, and the unrelated condition, $t(16) = 2.84$, $p = .012$, $d = 0.97$, but not for the phonological priming through translation condition. $t(16) = 0.67$, $p = .51$, $d = 0.22$.

Growth curve analysis

Analysis conducted on aggreggated PTL scores examines only a compressed sample of the data set. Therefore, we turned to another analysis used in the visual world literature to assess change over time—growth curve analysis (see Mirman, Dixon, & Magnuson, 2008, for a detailed description). Comparing phonological priming and unrelated trials, condition had a significant effect on the intercept of the model, $\chi^2(1) = 17.88$, $p = .0001$, but not on the slope, $\chi^2(1) = 0.18$, $p = .67$. This suggests a consistent facilitation effect for the phonological priming relative to the unrelated condition across the entire time course of the trial. Comparing phonological priming through translation and unrelated trials, condition once again had a significant effect on the intercept, $\chi^2(1) = 3.95$, $p = .047$, but not on the slope, $\chi^2(1) = 0.21$, $p = .65$. In contrast to the analysis using aggregated PTL measures reported above, this suggests a consistent interference effect across the time course of the trial for the phonological priming through translation condition compared with the unrelated condition.

Time course analysis

Visual inspection of the proportion of toddlers' fixations to the target across the time course of the trial revealed an intriguing differentiation of the three conditions around the first second after onset of the target word (see Fig. 2). Although there is reduced target looking in phonological priming through translation trials relative to unrelated trials, the two conditions appear to deviate from one another only around 1 s after the onset of the target word. To further analyze this pattern, we used a relatively new methodology for complementary time course analysis, namely, the nonparametric statistical test.

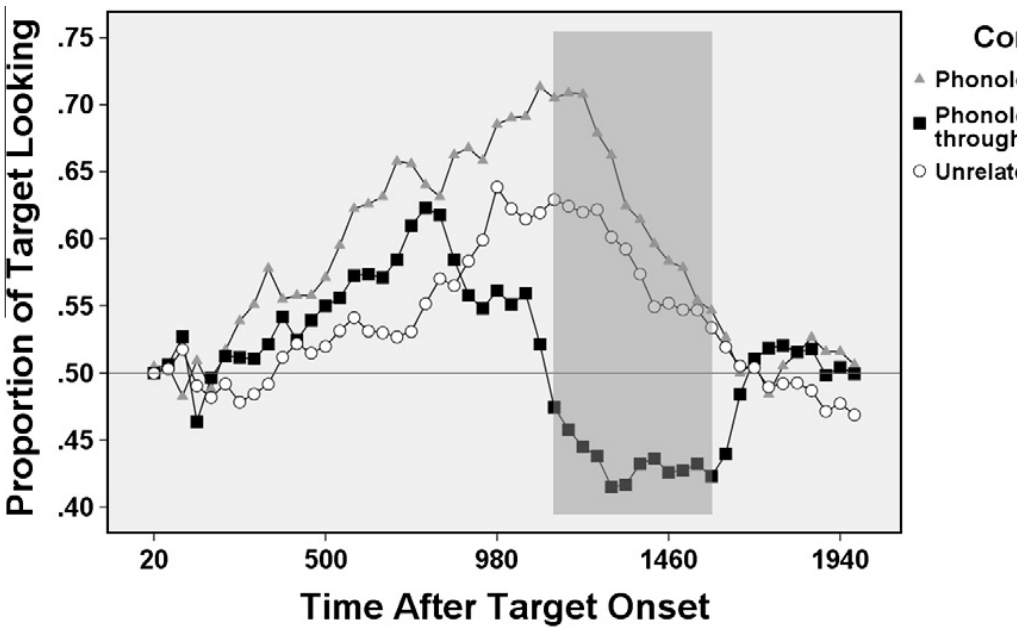

Fig. 2. Time course of toddlers' fixations in the phonological priming, phonological priming through translation, and unrelated conditions presented to children. Significant differences found between the phonological priming through translation and unrelated conditions using the nonparametric statistical test are highlighted with a shaded box ($p = .03$; 1140–1580 ms).

Briefly, the nonparametric statistical test is used to identify time periods across the time course of trials, where two conditions differ from one another, while avoiding the statistical problems of multiple comparisons (see Maris & Oostenveld, 2007, for more detail). Comparisons using the time course analysis revealed that the phonological priming through translation and unrelated conditions significantly deviated from each other between 2840 and 3280 ms (i.e., 1140–1580 ms after target word onset: cluster t statistic = 37.88, Monte Carlo $p = .03$), with reduced target looking in the former condition compared with the latter condition.

Monolingual priming study

Preanalysis

A 2 (Testing Block) × 3 (Condition) repeated measures ANOVA revealed no main effect of testing block, $F(1,14) = 0.32$, $p = .58$, and no significant interaction between testing block and condtion, $F(2,13) = 0.32$, $p = .73$. A repeated measures ANOVA with condition as a within-participants factor and age of the participants (range = 707–1338 days) as a covariate was conducted and showed no significant interaction between age and condition, $F(2,14) = 0.20$, $p = .82$. Therefore, all analyses are carried out collapsed across age and testing block.

Main analysis

A repeated measures ANOVA with the factor condition (phonological priming: $M = .54$, $SD = .07$; phonological priming through translation: $M = .52$, $SD = .07$; unrelated: $M = .54$, $SD = .06$) found no significant main effect of condition, $F(2,15) = 0.97$, $p = .40$. Target recognition was significantly greater than chance for both the phonological priming condition, $t(16) = 2.60$, $p = .02$, $d = 0.89$, and the unrelated condition, $t(16) = 3.29$, $p = .005$, $d = 1.14$, but not for the phonological priming through translation condition, $t(16) = 1.37$, $p = .19$, $d = 0.47$.

Time course analysis

To explore putative differences in the time course of the effects, we made comparisons using the Maris and Oostenveld (2007) time course analysis. The comparisons between the phonological priming and unrelated conditions revealed no differing time clusters, and comparisons between the phonological priming through translation and unrelated conditions ($p = .31$) were not significant.

Item analysis

To investigate why target recognition for phonological priming through translation words was not significantly greater than chance for the monolingual toddlers, we took a closer look at the items by comparing primed and unprimed trials, which should show no difference for monolingual toddlers. This comparison revealed that the difference between phonological priming through translation and unrelated trials approached significance for only one item, namely, "Buch" (*book*), $t(16) = –2.09$, $p = .06$, $d = 0.86$. Furthermore, the proportion of target looking for "Buch" was consistently lower than those for other items across both monolinguals and bilinguals. Might the interference effect in the phonological priming through translation condition in the bilingual data have been driven by this item?

Therefore, we ran an additional analysis of the bilingual toddler data excluding the item "Buch" to ensure that the interference effect found in the bilingual priming study was not driven by this item. A repeated measures ANOVA found a significant main effect of condition, $F(2,15) = 6.10$, $p = .012$, $\eta_p^2 = .45$. Separate pairwise analyses revealed that the phonological priming condition ($M = .60$, $SD = .07$) and the unrelated condition ($M = .55$, $SD = .07$) differed significantly, $t(16) = 2.64$, $p = .02$, $d = 0.66$, whereas the phonological priming through translation condition ($M = .53$, $SD = .09$) and the unrelated condition did not, $t(16) = –0.90$, $p = .38$, $d = 0.23$. However, comparisons using the Maris and Oostenveld (2007) time course analysis revealed that the phonological priming through translation and unrelated conditions significantly deviated from each other between 2860 and 3100 ms (i.e., 1160–1400 ms after target word onset: cluster t statistic = 33.76, Monte Carlo $p = .045$), with reduced target looking in the former condition compared with the latter condition. A similar analysis of the

monolingual toddlers (excluding the item "Buch") found no significant main effect of condition, $F(2,15) = 0.08$, $p = .92$, $\eta_p^2 = .01$. In addition, the unrelated condition ($M = .55$, $SD = .06$) still differed significantly from chance, $t(16) = 3.87$, $p = .001$, $d = 1.33$, and the phonological priming through tranlsation condition ($M = .56$, $SD = .08$) now also differed significantly from chance, $t(16) = 2.96$, $p = .009$, $d = 0.07$. Finally, a comparison of the phonological priming through translation and unrelated conditions using the Maris and Oostenveld (2007) time course analysis was not significant ($p = .22$).

In sum, excluding the item "Buch" from analysis does not alter the results for the monolingual priming study other than to demonstrate that target recognition is above chance for the phonological priming through translation condition. Importantly, exclusion of the item "Buch" does not change the results of the bilingual priming study. Although "Buch" was perhaps an inappropriate stimulus item for the current study, its inclusion or exclusion does not change the critical patterns and conclusions drawn from the current study.

Discussion

The current study presents the first investigation of language nonselective lexical access in bilingual toddlers. Word recognition in bilinguals' L1 was enhanced by previous exposure to a phonologically related word from bilinguals' L2, for example, *slide* (prime)–*Kleid* ("dress," target)—a facilitation effect. In addition, word recognititon in bilinguals' L1 was reduced by previous exposure to an L2 prime whose translation was phonologically similar to the L1 target, for example, *leg* ("Bein," prime and its German translation serving as subprime)–*Stein* "stone," target)—an interference effect. This effect was not due to toddlers not recognizing the words given that the same bilingual toddlers exhibited recognition of target words from this condition when tested in the naming study. Interestingly, the interference effect found for the phonological priming through translation condition began 1140 ms after the onset of the L1 target label. Interpretation of these findings as a result of cross-language activation is strengthened by the finding that monolingual toddlers, when tested on the same priming task, show no priming effects for any of the conditions. We first consider the differences in types of priming effect (facilitation and interference) before discussing the time course of the effects.

Differences in types of priming effect

L1 target recognition was facilitated when the L2 prime (*slide*) and L1 target (*Kleid,* "dress") pairs were phonologically related across languages compared with unrelated pairs (*slide–Huhn,* "chicken"). Similar facilitation effects from L2 primes to L1 targets have been reported in the adult bilingual literature (Costa et al., 1999; Van Wijnendaele & Brysbaert, 2002; Zhou, Chen, Yang, & Dunlap, 2010). Although this demonstrates cross-language activation between a bilingual's two languages, we should be cautious in interpreting these results as evidence of cross-language activation at the lexical level. That is, the facilitation effect need not necessarily imply that hearing the L2 prime activated the L1 lexical item. Such effects might merely imply that hearing the L2 prime activated the phonemes corresponding to this word, leading to faster recognition of the L1 target sharing a large proportion of these phonemes. Rather than demonstrating lexical-level connections, the facilitation effect observed in the phonological priming condition might be a result of acoustic- or phonological-level overlap.

Such an interpretation of our results is consistent with the monolingual literature on facilitation effects found in rhyming prime–target pairs (Norris et al., 2002). Given that facilitation effects are also found with nonword primes, but only when the prime and target both are auditorally presented (Cutler, Sebastián-Gallés, Soler-Vilageliu, & van Ooijen, 2000; Dumay et al., 2001; Radeau et al., 1995), the monolingual literature generally assumes that facilitation effects with rhyming pairs index prelexical processes in word recognition. Consequently, we avoid interpreting the results from the phonological priming condition as evidence of language nonselective lexical access in bilingual toddlers. Rather, we suggest that these results demonstrate that phonological information from one language can influence recognition of words from bilinguals' other language; that is, these results provide evidence of language nonselective *phonological* access.

In contrast, L1 target recognition was reduced when the L1 translation ("Bein") of the L2 prime (*leg*) rhymed with the L1 target (*Stein,* "stone"). We suggest that the interference effect in the phonological

priming through translation condition provides strong evidence of language nonselective lexical access in bilingual toddlers. This is in keeping with the interpretation of interference effects as evidence of lexical activation in both monolingual adults (Slowiaczek & Hamburger, 1992) and toddlers (Mani & Plunkett, 2011). Because the prime and target share no overt phonological overlap in the phonological priming through translation condition, an influence of the prime on the target cannot be driven by phonological-level cross-language activation. The finding of a priming effect implies that the L2 prime led to lexical-level access of its L1 translation equivalent. On access of the L1 translation equivalent, activation spread to the phonological level, influencing selection of the phonologically similar L1 target. Because the only way that *leg* could influence recognition of *Stein* is through activation of the L1 translation equivalent of *leg* (i.e., "Bein"), this finding provides conclusive evidence of language nonselective lexical access in bilingual toddlers.

The interference effect found in the phonological priming through translation condition provides an interesting addition to the limited bilingual adult literature on the topic (Costa et al., 1999). Although Costa et al. (1999) did not find evidence of a similar priming effect (but see Sunderman & Kroll, 2006, showing orthographical priming through translation), we suggest that differences in the task used in the current study (and Duyck, 2005) and in Costa et al. (1999) account for the differences in the results. Costa and colleagues used a picture naming task, requiring participants to produce the target label. In contrast, the current study employed a perceptual word recognition task, requiring participants to merely look at the image of the labeled target. We propose that this difference in task may underlie the difference in the results. One possibility is that in a perception task it is easier to keep mulitple candidates in play simultaneously while nevertheless favoring activation of the target. In contrast, in a production task, because the target needs to be unambiguously selected in order to provide the required production response, it may be detrimental to keep mulitple candidates in play.

We now turn to an examination of the locus of the interference effect found in the current study. There are two potential explanations for this effect. On the one hand, the source of interference might lie in the translation of the L2 prime to its L1 equivalent. On the other hand, L1 target recognition may be hindered due to simultaneous processing of its phonological competitor, that is, the L1 translation of the L2 prime.

Most studies examining L2–L1 translation priming have found a facilitation effect; participants are faster at naming an L1 target with previous exposure to its L2 translation equivalent (Basnight-Brown & Altarriba, 2007; Duyck & Warlop, 2009; Grainger & Frenck-Mestre, 1998; Phillips, Klein, Mercier, & de Boysson, 2006; Schoonbaert, Duyck, Brysbaert, & Hartsuiker, 2009). This makes it unlikely that the interference effects found in the current study stem from the translation of the L2 prime to its L1 equivalent. Nevertheless, differences between these studies and the current study in the age of the participants and the tasks employed make it difficult to directly relate these findings to the current study.

On the one hand, the interference found in the phonological priming through translation condition might have been caused by the presence of both languages within every trial (i.e., an English prime word and a German target word). Because English was heard first and (presumably) activated first, the recognition of a subsequently presented target in German might be inhibited regardless of the relationship between the prime and target words. However, if this were the case, we would also expect an interference effect in the phonological priming condition (where we observed a facilitation effect).

Might the interference effect stem from within-language effects caused by coactivation of phonologically similar L1 translations and L1 targets, that is, "Bein"–*Stein*? Indeed, recent studies with monolingual toddlers report interference effects in target word recognition due to previous exposure to phonologically related word onset primes, for example, *book–ball* (Mani & Plunkett, 2011). Mani and Plunkett (2011) suggested that target word recognition is reduced due to coactivation of other phonologically related words sounding similar to both the prime and the target. However, whereas onset priming in 2-year-olds results in interference effects (Mani & Plunkett, 2011), rhyme priming typically results in facilitation effects in 4- to 6-year-olds (Coch, Grossi, Skendzel, & Neville, 2005; Coch, Mitra, George, & Berger, 2011). Evidence from the current study also suggests facilitation in rhyme priming, although this was across languages. Therefore, the extent to which competitor effects from rhyme overlap underlie the results of the current study is debatable.

There is, therefore, no conclusive evidence linking the interference effects to any one stage in the process of phonological priming through translation. Indeed, phonological priming through translation requires cascaded activation of numerous levels of respresentation, which may place a considerable burden on target recognition overall. This speculatively locates the interference effects in the costs of maintaining multiple lexical candidates active at different levels of representation.

Delay in phonological priming through translation condition

The results of the current study highlight not only differences in the type of priming effect (facilitation or interference) but also the timing of the phonological priming through translation effects. We suggest that the delayed onset of the phonological priming through translation effect speaks to the processes underlying this effect; in the event-related potential (ERP) literature, components indexing lexical effects occur later, between 350 and 600 ms from the onset of a word, that is, N400 (Kutas & Hillyard, 1984). Although the onset of the phonological priming through translation effects was further delayed, this might be attributable to the additional amount of time needed to make a saccade. We suggest that the delay in onset of the interference effect in the phonological priming through translation condition similarly upholds a lexical-level influence on bilingual toddlers' target recognition in this condition.

Monolingual controls

Unlike their bilingual counterparts, the monolingual toddlers tested in the current study showed no difference in target recognition across the three conditions. We interpret this as further evidence that the results reported with bilingual toddlers index cross-language phonological and lexical access. In other words, the pattern of responding displayed by the bilingual toddlers is due to their activation of the sounds and words of both languages.

Modeling the bilingual lexicon in toddlers

Having demonstrated language nonselective phonological and lexical access, the current study asked what our findings mean for an overall understanding of the bilingual lexicon. To interpret the current results, we first turn to the revised hierarchical model (RHM; Kroll & Dijkstra, 2002; Kroll & Stewart, 1994; Kroll, van Hell, Tokowicz, & Green, 2010).

Revised hierachical model

The RHM focuses on the connections between L1 and L2 words at the lexical and conceptual levels. The RHM proposes that when L2 is first acquired, words in L2 are linked to their translation equivalents in L1, thereby providing L2 words with meaning information. As proficiency in L2 increases, conceptual information can be accessed from the L2 directly.

Relevant for the current study is the suggestion that L1 translation equivalents are routinely accessed during L2 processing, which fits the finding of language nonselective lexical access in the phonological priming through translation condition. According to the RHM, there are two pathways for such an influence. On the one hand, a direct lexical link could exist between the L2 prime and its L1 translation equivalent such that processing L2 words automatically retrieves their L1 translation equivalents. On the other hand, with greater L2 proficiency, lexical–conceptual links build up between L2 words and their conceptual content. Processing L2 words would lead to retrieval of the conceptual information associated with these words. Although L2 processing does not directly lead to retrieval of L1 translation equivalents, the latter are indirectly activated through lexical–conceptual links between L1 words and conceptual information. The current study was unable to tease apart the two RHM pathways underlying our findings; however, we note that both interpretations yield the same result: Processing of L2 words accesses the lexical entries for their L1 translation equivalents.

We omit a discussion of the phonological-level facilitation effects demonstrated in our phonological priming condition in terms of the RHM because the latter does not deal specifically with phonology.

Bilingual model of lexical access

The bilingual model of lexical access (BIMOLA; Grosjean, 1988; Grosjean, 1997; Grosjean, 2008) assumes that the bilingual lexicon consists of two language networks whose organization is independent but interconnected. Like the TRACE model of speech perception (McClelland & Elman, 1986), the language networks consist of three different levels of processing (feature, phoneme, and word) that are involved in word recognition. Phonemes from both languages are activated when the speech input overlaps with the phonological properties of sounds in the two languages. Inhibitory or facilitatory connections, however, exist only within-language and not between-language.

BIMOLA suggests that the within-language excitatory connections between levels, specifically between phonemes and words, will result in facilitated recognition of phonologically similar words regardless of language. This supports our finding in the phonological priming condition of the current study; recognition of a target word was facilitated when preceded by a phonologically similar (rhyming) prime word.

The findings of the current study diverge from BIMOLA with regard to the phonological priming through translation condition. BIMOLA does not provide a mechanism for cross-language lexical access. Grosjean (2008) specified that units within a level inhibit each other but that this inhibition remains within-language and has no influence on the other language. However, the current study demonstrates that lexical access of a word in one language (e.g., *leg*) leads to activation of its translation equivalent in the other language (''Bein''). This effect strongly suggests that words from one language can influence recognition of words from the other language, in contrast to BIMOLA's predictions.

PRIMIR: bilingual development in focus

Perhaps most suitable to explaining our results is the PRIMIR (Processing Rich Information from Multidimensional Interactive Representations) framework, which has been recently adapted to infants growing up in a bilingual environment (Curtin, Byers-Heinlein, & Werker, 2011). According to PRIMIR, the different representation spaces organize speech input based on the characteristics of that input. When the speech input comes from two different languages, words from one language are more likely to co-occur together. These words would naturally cluster together, organizing the language system in such a way that languages are naturally separated while nevertheless allowing for cross-language phono-lexical access. Language separation in bilingual infants is achieved through learning mechanisms structured by the nature of the input and the distributional statistics of each language. PRIMIR's conclusions on language separation are supported by recent experimental work showing auditory language discrimination (Bosch & Sebastián Gallés, 1997, 2001; Byers-Heinlein, Burns, & Werker, 2010) and effects of user-specific language clustering in bilingual 2-year-olds (Genesee, Boivin, & Nicoladis, 1996).

With regard to the results of the current study, PRIMIR provides a most suitable framework allowing for both cross-language phonological and lexical access while nevertheless suggesting stronger within-language effects relative to cross-language effects (a suggestion that requires further experimental validation). However, we note that our results could just as easily be explained by a single combined phono-lexical system (as in PRIMIR) as by postulating two separate but highly connected lexicons, as suggested by some of the other models reviewed above.

Future directions

Important for future studies will be the continued investivation of language nonselective lexical access in bilingual toddlers. As mentioned above, the current study was unable to identify the locus of the interference effect in the phonological priming through translation condition. New studies are needed to determine whether this effect is due to within-language effects caused by coactivation of phonologically similar L1 translations and L1 targets (e.g., ''Bein''–*Stein*) or whether it is the result of the cost of maintaining multiple lexical candidates active at different levels of representation. In addition, the current study investigated priming only in the direction of L2–L1. However, research with bilingual adults suggests that there may be assymmetrical priming effects depending on the direction of priming (Basnight-Brown & Altarriba, 2007; Dimitropoulou, Duñabeitia, & Carreiras, 2011; Duyck & Warlop, 2009; Jiang & Forster, 2001), whereas other research has found no difference

between L2–L1 and L1–L2 priming (Duñabeitia, Dimitropoulou, Uribe-Etxebarria, Laka, & Carreiras, 2010; Schoonbaert et al., 2009; Van Wijnendaele & Brysbaert, 2002). Resolving these differences in adult bilinguals and extending them to the study of bilingual toddlers will be crucial to understanding the organization, activation, and development of the bilingual lexicon.

Conclusion

By comparing the direction of priming effects in phonological priming with that of phonological priming through translation, we have shown that phonological priming effects between languages do not necessarily imply language nonselective lexical access and may instead be the result of cross-language phonological-level connections. However, the best explanation for the interference effect found in our phonological priming through translation condition is access of the lexical entry for the L1 translation equivalent of the L2 prime or language nonselective lexical access. Therefore, the current study provides compelling evidence for cross-language phonological and lexical access in bilingual toddlers and distinguishes these effects from one another in a manner yet to be established in the adult bilingual literature.

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