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Cross-linguistic influence in the simultaneous bilingual child's lexicon: An eye-tracking and primed picture selection study

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Abstract

In a between-language lexical priming study, we examined to what extent the two languages in a simultaneous bilingual child's lexicon interact, while taking individual differences in language exposure into account. Primary-school-aged Dutch–Greek bilinguals performed a primed picture selection task combined with eye-tracking. They matched pictures to auditorily presented Dutch target words preceded by Greek prime words. Their reaction times and eye movements were recorded. We tested for effects of between-language phonological priming, translation priming, and phonological priming through translation. Priming effects emerged in reaction times and eye movements in all three conditions, at different stages of processing, and unaffected by language exposure. These results extend previous findings for bilingual toddlers and bilingual adults. Processing similarities between these populations indicate that, across different stages of development, bilinguals have an integrated lexicon that is accessed in a language-nonselective way and is susceptible to interactions within and between different types of lexical representation.

1. Introduction

When bilingual children speak in one of their languages, they may be influenced by elements from their other language, such as word order or word choice preferences. In the field of child bilingualism, this is referred to as cross-linguistic influence (CLI). Most CLI research in bilingual children has focused on the morpho-syntactic level (see van Dijk et al., 2021, for a review). At the lexical level, interactions between languages are well established in bilingual adults, but they have been much less extensively studied in bilingual children. In this study, we focus on CLI at the lexical level in bilingual children. For example, when a Dutch–Greek bilingual child hears the Dutch word *koekje* "cookie", she might think of her doll (Dutch: *pop*), because the Greek word for doll, *κούκλα* /ˈkukla/, sounds similar to *koekje* /ˈkukjə/. The presence of CLI at the lexical level would be consistent with the view that words from both languages are stored in one lexicon (i.e., an integrated lexicon rather than two separate lexicons), a view which is widely shared with respect to adults (see Dijkstra, 2005, for a review). In this study, we test to what extent bilingual children also make use of an integrated lexicon, by considering the interaction and co-activation of semantic and phonological codes in Greek and Dutch during auditory word comprehension.

Current models of (adult) bilingual word retrieval predict CLI at the lexical level as a consequence of two assumed properties of the bilingual mental lexicon: i) interconnected semantic, phonological, and/or orthographic representations of both languages, and ii) language-nonselective access to the lexicon (e.g., Dijkstra et al., 2019; Dijkstra & van Heuven, 2002; Shook & Marian, 2013). This means that representations can become activated and interact with each other regardless of the language they belong to. For example, in many models (Dijkstra et al., 2019; Dijkstra & van Heuven, 2002; Shook & Marian, 2013) semantic representations are largely shared between languages. When a word is encountered in one language, the translation equivalent also becomes activated via the shared semantic representation. This results in CLI at the level of semantic representations (e.g., Basnight-Brown & Altarriba, 2007; Dimitropoulou et al., 2011b; Duyck & Warlop, 2009; Gollan et al., 1997).

To explain CLI between words with similar phonology, such as the interaction between /ˈkukla/ and /ˈkukjə/ in our example, we turn to the influential Bilingual Interactive Activation plus (BIA+) model (Dijkstra & van Heuven, 2002), depicted in Figure 1. Applied to auditory word comprehension, CLI occurs because sub-lexical phonological representations (i.e., phonemes) are shared between languages. When the phonemes corresponding to /ˈkukla/ become

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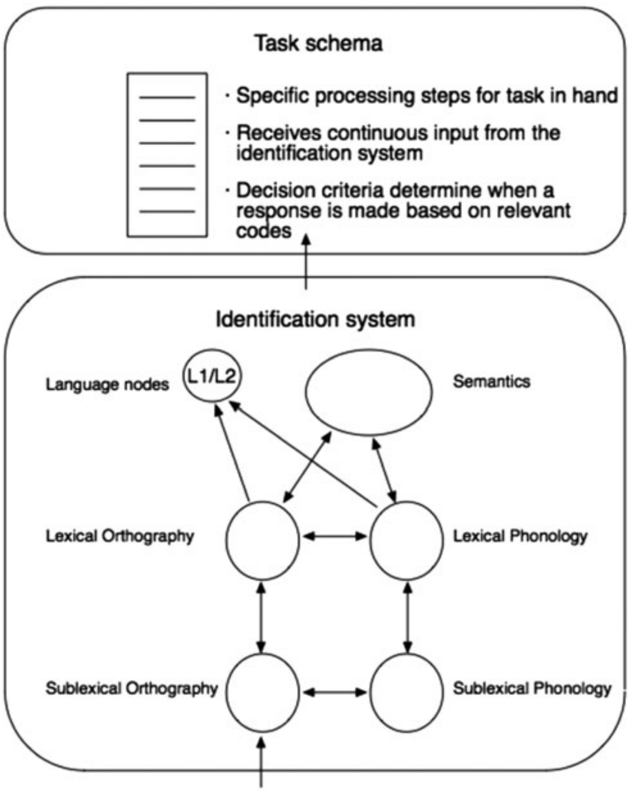

Figure 1. The Bilingual Interactive Activation plus (BIA+) model (Dijkstra & van Heuven, 2002).

activated, multiple (partly) matching lexical phonological representations (i.e., word forms) from both languages become co-activated, so not only the Greek word form /'kukla/, but also the Dutch /'kukjə/. This results in CLI at the level of phonological representations (e.g., Dimitropoulou et al., 2011a; Jouravlev et al., 2014; Nakayama et al., 2012; Van Wijnendaele & Brysbaert, 2002).

The degree to which CLI at the lexical level emerges depends on several factors. The most well-studied factors relate to language dominance and include language proficiency and exposure. In the BIA+ (Dijkstra & van Heuven, 2002) and Multilink models (Dijkstra et al., 2019), more exposure to a language leads to a higher resting-level activation for words belonging to that language. The higher the resting-level activation, the faster words are (co-)activated, and the more influence they exert over other words. Indeed, in many adult studies, words from a more proficient language – usually the language in which participants have had most exposure – have been found to influence words from a less proficient language more than the other way around (see van Hell & Tanner, 2012, for a review).

In sum, bilingual word retrieval models assume that word forms and meanings are represented in an integrated lexicon with language-nonselective access. As a consequence, representations from different languages interact during processing. CLI can emerge when words share their meaning and/or overlap in their phonological form, and the degree to which CLI takes place is sensitive to factors relating to language dominance. Whilst these types of effects are well established in the adult literature (e.g., Dijkstra, 2005; van Hell & Tanner, 2012), CLI at the lexical level has only been investigated relatively recently in simultaneous bilingual children.

1.1. The lexicon of bilingual children

Studies on lexical CLI in bilingual children have mostly used between-language lexical priming paradigms (Floccia et al., 2020; Jardak & Byers-Heinlein, 2019; Poarch & van Hell, 2012; Singh, 2014; Von Holzen & Mani, 2012). In a lexical priming task, participants are presented with a sequence of two (related) words. A priming effect ensues when the properties of the first word (i.e., the prime) influence the processing of the second word (i.e., the target), and is seen as evidence for interactive connections between representations in the lexicon. For example, Von Holzen and Mani (2012) conducted a preferential looking study using between-language lexical priming with German–English bilingual toddlers. Children heard English primes followed by German targets and were subsequently shown two images, one of which corresponded to the target. In the phonological priming condition, where prime and target rhymed with each other (e.g., *slide* – *Kleid* "dress"), a facilitatory priming effect was found: children's looks to the target image increased compared to a control condition in which prime and target were unrelated. In addition, the authors observed an inhibitory effect of phonological priming through translation: when the German translation of the English prime rhymed with the German target (e.g., *leg* – *Stein* "stone", related via *Bein* "leg"), the proportion of looks to the target image decreased. These priming effects between words from different languages suggest that as for adults, in bilingual children words from both languages are represented in an integrated lexicon with language-nonselective access, where hearing a word in one language activates its translation, and form-similar words to both the prime and its translation become co-activated.

Other studies with bilingual toddlers have revealed different types of between-language priming, while also investigating the role of language dominance (Floccia et al., 2020; Jardak & Byers-Heinlein, 2019; Singh, 2014). For example, using the same paradigm as Von Holzen and Mani (2012), Singh (2014) found between-language facilitatory semantic priming (e.g., *table* – *chair*) effects in English–Mandarin Chinese simultaneous bilingual toddlers. Furthermore, priming was influenced by dominance, operationalized as relative language exposure: between-language priming was only found from the dominant to the non-dominant language. In a similar study, Jardak and Byers-Heinlein (2019) found between-language facilitatory semantic priming in French–English simultaneous bilingual toddlers. However, in their study, priming was unaffected by dominance, which was operationalized as relative vocabulary size, even though the authors' hypotheses were in fact based on exposure. Finally, in a study on bilingual toddlers from diverse language backgrounds, Floccia and colleagues (2020) found facilitatory translation priming (e.g., *cheese* – *fromage* "cheese") and between-language semantic priming (e.g., *dog* – *chat* "cat"), and in line with Jardak and Byers-Heinlein (2019), this was unaffected by dominance, operationalized as relative exposure.

Taken together, the available between-language priming studies suggest that, like bilingual adults, young simultaneous bilinguals have a lexicon that is integrated, with shared semantic and sub-lexical phonological representations, and with language-nonselective access. The flow of activation between semantic, lexical phonological, and sub-lexical phonological representations in such a lexicon is presented in Figure 2. Because the available research on between-language lexical priming in children comes from bilingual toddlers only, it remains unclear to what extent languages in the lexicon interact at later stages of child development. In addition, because of practical

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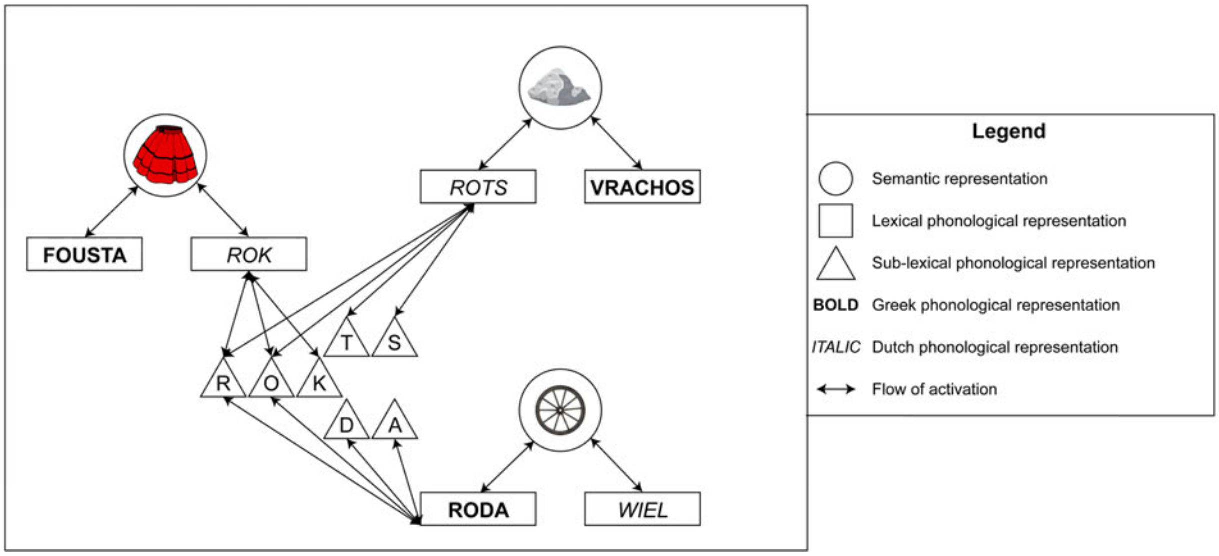

Figure 2. Flow of activation in an integrated Dutch–Greek bilingual lexicon. In comprehension, activation spreads from phonological representations derived from the input to semantic representations, and results in co-activation of various sub-lexical and lexical units.

limitations in testing such young children, most studies have focused on one type of representation and have used eye-tracking paradigms. As such, these studies are quite different from adult studies, which have mainly used reaction time (RT) measures, and it is not clear to what extent the effects are comparable. To address these gaps, the present study focused on school-aged children – a population in between toddlers and adults in terms of age – combining methods used in toddler studies (namely, eye-tracking) and adult studies (namely, RT measurements).

1.2. Present study

In order to investigate CLI at the lexical level in bilingual children, we conducted a between-language lexical priming study with Dutch–Greek simultaneous bilinguals aged between four and nine years old. Testing an older population than in previous child studies not only contributes to our understanding of the bilingual lexicon at different ages, but also allowed us to examine multiple types of lexical priming and use multiple measures in one study. We conductedan eye-tracking task, similar to the primed preferential looking tasks described above but also incorporating picture selection. Measuring both eye movements and RTs means that our study is comparable with both toddler and adult studies. In addition, we included a measure of language exposure, in line with previous research by Floccia and colleagues (2020) and Singh (2014), as well as the predictions following from the BIA+ model (Dijkstra & van Heuven, 2002) and Multilink (Dijkstra et al., 2019).[1]

First, we tested for between-language phonological priming and translation priming effects from Greek to Dutch and predicted that such effects would take place in both types of priming. A phonological priming effect would suggest that auditory input co-activates corresponding word forms from both languages via shared sub-lexical phonological representations, as in the BIA+ model and our adaptation for auditory processing in children (Figure 2). A translation priming effect would obtain if translation equivalents are connected via a largely common meaning representation (Figure 2; see also Dijkstra et al., 2019; Dijkstra & van Heuven, 2002; Shook & Marian, 2013).

Second, we tested for effects of phonological priming through translation from Greek – via Dutch – to Dutch. Following Von Holzen and Mani (2012), we assumed that interactions between phonological and semantic representations from both languages would result in such priming effects. Specifically, as in translation priming, encountering a word in one language would lead to activation of its translation equivalent; next, as in phonological priming, form-similar words to the translation equivalent would be activated via sub-lexical phonological representations. For example, encountering the Greek word *vrachos* would lead to activation of its Dutch translation *rots* (see Figure 2); next, form-similar words to *rots* would be activated, including the Dutch target word *rok*. (Both *vrachos* and *rots* translate to "rock"; *rok* translates to "skirt", but note that these English translations were not available to the children.)

Although previous studies did not always find effects of children's language exposure, we predicted that individual differences on this variable would affect CLI. Following the BIA+ and Multilink models, where more exposure leads to higher resting-level activation, we predicted that words from a dominant language would be (co-)activated faster than words from a non-dominant language. Specifically, for children with higher proportions of Greek exposure relative to Dutch exposure, Greek words would be co-activated faster than Dutch words. As such, a stronger influence of Greek on Dutch would appear in the priming conditions for children with higher proportions of Greek exposure than for children with lower proportions of Greek exposure, in the form of faster responses and increased target looks at an earlier stage. These language exposure effects would be in line with previous studies on toddlers (Singh, 2014) and adults (e.g., Chaouch-Orozco et al., 2021).

2. Method

2.1. Participants

Participants were 24 bilingual Dutch–Greek children, who had all received substantial input in Greek and Dutch, defined as minimally half a day per week, since before the age of four and for the

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vast majority ($n = 18$) since birth. Children were aged between 4.6 and 9.2 years old ($M = 6.9$, $SD = 1.6$) and mostly came from higher socio-economic backgrounds, measured in terms of parental education: for 22 children, at least one parent had obtained a (applied) university degree. Two additional children had been tested, but their data were excluded; see Data Exclusion.

All children lived in the Netherlands. Some children had (had) exposure to languages other than Dutch and/or Greek, but this was either much earlier in their lives (at least 3.5 years prior to testing; $n = 2$) or limited to no more than an hour (of English) at school. All children had acquired Greek from at least one parent or caregiver in their home environment. In some cases ($n = 5$), both parents were native speakers of Greek and had migrated to the Netherlands at a later age (for instance, for work or studies); for most ($n = 16$) this was the case for one parent and the other parent was a native speaker of Dutch. For three children, one parent was born in the Netherlands to Greek-speaking parents who had moved to the Netherlands themselves, while the other parent was Dutch ($n = 1$) or had moved to the Netherlands from Greece as an adult ($n = 2$). In addition to receiving input from family members, some children ($n = 6$) followed Greek language classes as an after-school activity.

Table 1 summarizes children's scores on a range of background variables: working memory (Dutch version of Alloway Working Memory Assessment – Forward and Backward Digit Span Tests: Alloway, 2012), Dutch lexical proficiency (LITMUS Cross-linguistic Lexical Task: Haman et al., 2015; van Wonderen & Unsworth, 2021), Greek lexical proficiency (adaptation of Greek Child Action and Object Test: Kambanaros et al., 2013), Dutch and Greek syntactic proficiency (LITMUS Sentence Repetition Task: Marinis & Armon-Lotem, 2015) and relative current exposure (Bilingual Language Experience Calculator: Unsworth, 2013).

2.2. Materials

The stimuli consisted of pre-recorded prime and target words, and target and distractor images. The target words were 28 Dutch nouns. Each target was matched to one distractor image and four Greek prime words. Primes, targets, and distractors were noncognate nouns from word lists expected to be known by young Dutch children (Dunn et al., 2005; Mulder et al., 2009; Schlichting & Lutje Spelberg, 2002; Zink & Lejaegere, 2002), with a reported age of acquisition (AoA) below 8;0 (Brysbaert et al., 2014), and their Greek translations. The four Greek primes for each target were selected based on semantic and/or phonological overlap with the target; see Table 2. The prime in the control condition – as well as its translation – was semantically and phonologically unrelated to the Dutch target and its translation. The prime in the phonological priming condition overlapped with the target on, minimally, the phonemes in the onset and nucleus of the first syllable[2], and was semantically unrelated to the target. The prime in the translation priming condition was the translation equivalent of the target, and had minimal phonological (onset) overlap with the target. In the phonological-priming-through-translation condition, the prime's translation overlapped phonologically (based on word onset, as in the phonological priming condition) with the target (Greek-Dutch-Dutch phonological priming through translation, equivalent to Von Holzen & Mani, 2012).

Table 1. Overview of participant characteristics.

Background variable	*M*	*SD*	Range
Working Memory[a]:			
• Forward Digit Span Test score	93	13	64–112
• Backward Digit Span Test score	100	13	81–124
Dutch Proficiency:			
– Lexical proficiency score	70%	19%	28%–96%
– Syntactic proficiency score	61%	26%	20%–97%
Greek Proficiency:			
– Lexical proficiency score	44%	19%	4%–88%
– Syntactic proficiency score	5%	10%	0%–32%
Percentage Greek Exposure	37%	14%	15%–69%

[a]Scores are standard scores, with possible scores ranging from 47 to 153.

Table 2. Priming conditions per session, with examples.

Type of overlap	Condition	Example
None (control)	Unrelated priming	*psari* "fish" – *rok* "skirt"
Phonological	Phonological priming	*roda* "wheel" – *rok* "skirt"
Semantic	Translation priming	*fousta* "skirt" – *rok* "skirt"
Phonological and semantic	Phonological priming through translation	*vrachos* "rock" – (*rots* "rock") – *rok* "skirt"

Overall, we aimed to minimize differences in frequency (Dimitropoulou et al., 2010; Keuleers et al., 2010); age of acquisiton (AoA) (Brysbaert et al., 2014)[3], and length (in phonemes) between the sets of primes and targets. It was not possible to fully match items – for instance, in translation priming where a Greek translation would often be longer than the Dutch target. For that reason, frequency, AoA, and length were included as covariates in the analyses (see Analysis). A list of all stimulus words with frequency, AoA, and length as well as measures of phonological (Levenshtein Distance) and semantic distance (Snaut: Mandera et al., 2017) between primes and targets is included as online Supplementary Materials.

The final 28 Dutch target words and 112 Greek prime words were recorded by a female bilingual native speaker of Dutch and Greek. Prime-target combinations were divided over four blocks of 28 trials. Each target word appeared in a different condition (i.e., paired with a different prime) per block and each block contained seven items per condition.

The 28 target and 28 distractor images were full-color clip-art images, sized 512 × 512 pixels. Distractor images were similar to their matched targets in terms of color and visual complexity, based on the combined intuitions of four judges (the authors). Distractor images were semantically and phonologically (in both Dutch and Greek) unrelated to their matched prime and target words.

2.3. Procedure

All children were tested individually, in a quiet room in their home, by a Greek-speaking experimenter. Parents signed informed consent forms prior to the testing session. A 15.6-inch, 1366 × 768-pixel laptop with a Tobii Pro X3-120 eyetracker was placed on a table, and two response buttons were placed on either side of the laptop. The child was seated 60-70 cm from the laptop screen. Two 50 × 30 cm black screens were used to regulate light and block potential distractions. The main task was programmed in OpenSesame 3.2.5 (Mathôt et al.,

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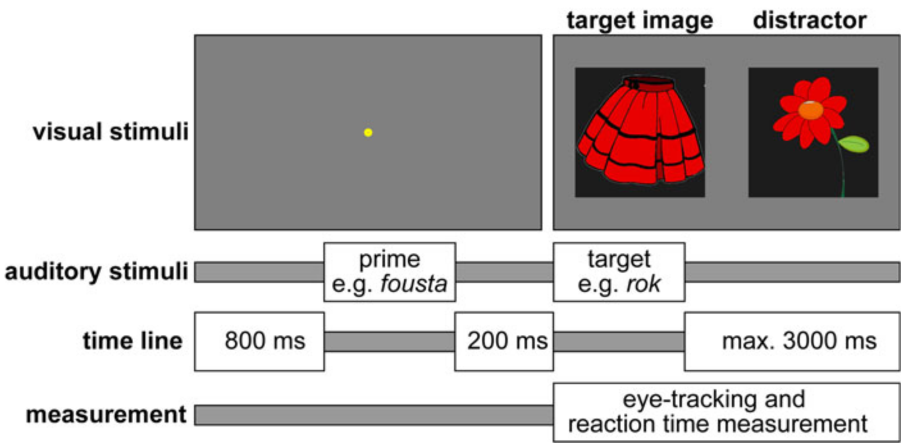

Figure 3. Timeline of a trial, with visual and auditory stimuli.

2012), using the PyGaze plugin (Dalmaijer et al., 2014). Audio was played through headphones.

The task consisted of four blocks of 28 trials. Block order was rotated over participants. Block-internal item order was randomized per participant, with minimized semantic and phonological overlap between subsequent trials and maximally two subsequent trials of the same condition.

An experimental trial (Figure 3) started by showing a yellow fixation symbol on a gray background. After 800 ms, the prime word was played. Next, after prime offset and a 200 ms pause, the target word was played. Simultaneously, the fixation symbol was replaced by the target and distractor images side by side. The location of the target image (left or right side of the screen) was evenly divided within blocks, and counterbalanced between blocks for each target. From target word offset, participants had up to 3000 ms to select the corresponding image by pressing a response button (left-hand button for left-hand image; right-hand button for right-hand image). Accuracy and RT data were obtained through these button presses. Eye movements were recorded throughout the trial.

To increase children's engagement and conceal the purpose of the task, the task was embedded in a scavenger-hunt-themed game. It followed two characters who were lost in a museum and were trying to find each other by listing the items they had seen on their way (i.e., the prime and target words). By choosing the correct image, the participant helped the characters choose which way to go in the museum.

Each block started with eye-tracker recalibration and two (in the last block) to five (in the first block) practice trials. Greek proficiency tests were administered in between the blocks of the main task. Dutch proficiency tests and other background tests were administered in a separate session. A testing session lasted 60-70 minutes, including short breaks between the tasks if needed. Children received stickers and a Greek-language book for their participation.

2.4. Analysis

RT data and eye-tracking data were analyzed separately in R version 4.1.2 (R Core Team, 2021). Plots were created using the ggplot2 package version 3.3.5 (Wickham, 2016).

Reaction time analyses

RTs were analyzed in a linear mixed-effects regression model with the lmer function from the lme4 package version 1.1.27.1 (Bates et al., 2015). Only correct trials were analyzed (see Data Exclusion). RTs were log-transformed, approaching a normal distribution (Baayen & Milin, 2010). Treatment coding was applied to *Condition*, with the control condition as the reference level. The continuous predictor *Percentage Greek Exposure* and continuous item variables (*Frequency*, *AoA*, and *Length* of prime and target) were mean-centered.

The model included *Condition* and *Percentage Greek Exposure* as predictors for *logRT*, as well as the interaction between the predictors and random intercepts for *Participant* and *Target*. Several covariates were added to the model in a stepwise manner – namely, item variables (*Frequency*, *AoA*, and *Length* of prime and target) and task variables (*Trial Number*, *Previous Trial Accuracy*, and *Previous Trial logRT*). The item variables were included because of differences between conditions, discussed above. The task variables that we included may influence RTs (see e.g., Lemhöfer et al., 2008) and were included to control for this influence as much as possible. To avoid overfitting, however, we only included those covariates that significantly improved the model, as was established through Likelihood Ratio Tests using the base anova function (R Core Team, 2021).

In the final model, *p*-values were obtained using Type 2 conditional *F*-tests with Kenward-Roger approximation for degrees of freedom (see Schaalje et al., 2002) as implemented in the Anova function of the car package version 3.0.12 (Fox & Weisberg, 2019). Post-hoc tests were carried out using the emmeans and emtrends functions of the emmeans package version 1.7.2 (Lenth, 2022), using the contrast method trt.vs.ctrl to compare the reference level to each priming condition.

Eye-tracking analyses

Following Von Holzen and Mani (2012), the eye-tracking data were analyzed with bootstrapped cluster-based permutation analyses (Maris & Oostenveld, 2007), using the eyetrackingR package version 0.2.0. (Forbes et al., 2021). Only correct trials were analyzed (see Data Exclusion). The dependent variable was the logit-adjusted proportion of gaze towards the target, averaged over bins of 30 ms, starting from target onset and ending after 1500 ms.[4] Because bootstrapped cluster-based permutation analysis contrasts two levels at a time, we performed separate analyses for *Condition* and *Percentage Greek Exposure*, and recoded the latter predictor from a continuous variable to a binary variable, using a median split.

For *Condition*, we repeated the following procedure for each priming condition as the treatment level, with the control condition as the reference level. A linear regression model with *Condition* as a predictor for *gaze* was run on each time bin. For

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each cluster of one or more adjacent bins with a *t*-value of at least 2, the sum of *t*-values was calculated. Next, 1000 simulations were run in which this procedure was repeated on randomly shuffled data, and the largest summed *t*-value of each simulation was saved. The *p*-value of the original cluster was then obtained by comparing its summed *t*-value with the distribution of the simulated *t*-values: the effect of the predictor in a cluster was considered significant if the summed *t*-value of that cluster was larger than 95% of simulated summed *t*-values, corresponding to $p < .05$.

To analyze the effects of *Percentage Greek Exposure*, we first performed bootstrapped cluster-based permutation analyses to test for effects of *Percentage Greek Exposure* within each condition. If this revealed significant differences within a condition between participants with higher Greek exposure and participants with lower Greek exposure, follow-up models were run where we tested for differences between conditions (i.e., priming effects) within each subset of participants.

3. Results

3.1. Data exclusion

In 3.5% of trials, responses were missing due to recording errors. Data from two children were excluded, because high error rates throughout the session indicated that children did not understand the task (error rates of 53% and 50%, compared to maximally 10% for the other 24 children). In addition, two different target words were excluded from two different children, because high error rates suggested that they were unfamiliar with the target word or image (i.e., three incorrect responses out of four). After participant and target word exclusion, error rates were ≤10% per participant and per target.

Only trials with correct responses within 2500 ms after target onset and within 2.5 SD from participant average were included in the RT and eye-tracking analyses. This resulted in exclusion of 7% of all valid trials after participant and target exclusion, or 4% of correct trials, leaving a total of 2680 trials. Finally, in the eye-tracking analyses, only trials with less than 25% trackloss were included. This resulted in exclusion of another 129 trials from different participants, leaving a total of 2551 trials. At the participant level, trackloss was always <25%.

3.2. Reaction time results

The descriptive RTs (after data exclusion) are presented in Table 3; see also Appendix B for a plot. The final model is presented in Table 4. There were main effects of *Condition* and *Percentage Greek Exposure*. For *Condition*, post-hoc comparisons revealed significant facilitatory effects of phonological priming ($t(2367) = -3.77$, $p < .001$) and translation priming ($t(2367) = -3.30$, $p = .003$), but no significant effect of phonological priming through translation ($t(2367) = -1.84$, $p = .17$). For *Percentage Greek Exposure*, RTs increased with higher proportions of Greek exposure. Put differently, participants with higher proportions of Dutch exposure responded faster. There was no significant interaction between *Percentage Greek Exposure* and *Condition*.

Table 3. Reaction time means and standard deviations per condition, in milliseconds.

Condition	Mean RT in ms (*SD*)
Unrelated priming	1131 (361)
Phonological priming	1079 (331)
Translation priming	1086 (344)
Phonological priming through translation	1098 (338)

3.3. Eye-tracking results

The eye-tracking analysis revealed a significant phonological priming effect between 300 and 540 ms after target onset (summed *t*-statistic = 27.19; $p = .016$), a significant translation priming effect between 480 and 780 ms (summed *t*-statistic: 30.32; $p = .013$), and a significant phonological priming effect through translation between 270 and 600 ms (summed *t*-statistic = −44.44; $p = .001$). As shown in Figure 4, in phonological priming and phonological priming through translation, gaze towards the target image decreased during the significant time windows. In general, these inhibitory priming effects took place while children were listening to the target word. The translation priming effect was facilitatory, with increased looks to the target compared to the control condition. *Percentage Greek Exposure* did not affect target gaze in any of the conditions.

4. Discussion

This study investigated cross-linguistic influence (CLI) at the levels of semantic and phonological representations in the lexicon of school-aged simultaneous Dutch–Greek bilinguals. Children completed a primed picture selection task combined with eye-tracking, where both eye movements and RTs were measured. The task included between-language phonological priming, translation priming, and phonological-priming-through-translation conditions. In addition, we tested whether any priming effects were influenced by individual differences in language exposure.

As predicted, we found between-language phonological and translation priming effects in children's eye movements as well as their RTs. In line with our predictions, we found effects of phonological priming through translation, but only in children's eye movements. We discuss these findings in Section 4.1.

Our predictions for individual differences in priming behavior relating to language exposure were not supported: there was a main effect of exposure where children with more Dutch exposure responded more quickly to the Dutch target, but we did not find any interaction effects between priming condition and relative exposure in this study. These results are discussed in Section 4.2.

4.1. Cross-linguistic influence at multiple levels of representation in the lexicon

Overall, the observed between-language priming effects indicate that, like bilingual adults, bilingual children are in possession of a fully integrated lexicon. Form and meaning representations of words from both languages are connected interactively and access to the lexicon is language-nonselective.

In the phonological priming condition, children's behavior reflected CLI at multiple phases of auditory processing. Early on in the trial, children looked towards the target image less after hearing a (Greek) prime that was phonologically related to the (Dutch) target. This effect largely overlapped with the auditory presentation of the target word. Such early inhibition effects are typically associated with competition between lexical

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Table 4. Parameter estimates and results from significance tests of the final model of between-language priming in bilingual children.

	Parameter estimates		Significance tests		
Predictor	*B*	*SE*	*F*	*df*, $df_{residual}$	*p*
(Intercept)	5.838	0.126			
Condition: - Phonological prime (vs. unrelated)	−0.049	0.013	5.783	3, 2366.9	.001
- Translation prime (vs. unrelated)	−0.043	0.013			
- Phonological prime through translation (vs. unrelated)	−0.024	0.013			
Percentage Greek Exposure	0.492	0.221	4.308	1, 22.1	.050
Condition x Percentage Greek Exposure: - Phonological prime x Percentage Greek Exposure	−0.057	0.096	0.278	3, 2367.1	.842
- Translation prime x Percentage Greek Exposure	−0.052	0.098			
- Phonological prime through translation x Percentage Greek Exposure	−0.087	0.097			
Trial Number	−0.000	0.000	11.201	1, 2367.7	.001
Previous Trial logRT	0.168	0.017	93.453	1, 2396.9	<.001

Note. The significance tests reported in this table apply to predictors (e.g., *Condition*), not the individual levels of factors (e.g., the different conditions). The parameter estimates apply to the individual levels.

phonological representations (Dufour, 2008): when sub-lexical phonological representations are activated, this subsequently activates all lexical phonological representations that (partly) match, and these words start to compete for selection. This inhibitory phonological priming effect between words from different languages provides clear evidence for language-nonselective access and language-nonselective competition in auditory word processing (see Figure 5, left panel). This is in line with previous research with bilingual adults for visual and auditory word processing (e.g., Spivey & Marian, 1999; Weber & Cutler, 2004) and with the predictions following from the BIA+ model (Dijkstra & van Heuven, 2002).

At the end of the trial, when children selected the target image, they did so more quickly after hearing a phonologically related prime than after hearing an unrelated prime. This facilitatory phonological priming effect may seem in contradiction with the inhibitory effect found earlier on, but it is in fact in line with studies showing that timing affects the direction of phonological priming effects. For example, Hermans and colleagues (1998) found that between-language phonological effects can be inhibitory as well as facilitatory, depending on stimulus onset asynchrony. More specifically, longer intervals between prime and target lead to facilitatory phonological priming effects and are more generally associated with processes other than phonological competition, which has been shown to emerge with shorter inter-stimulus intervals (Dufour, 2008). In our study, we did not directly manipulate stimulus timing, but our different measures nevertheless tapped into different phases of lexical processing. Specifically, whilst our eye-tracking measures reflected phonological competition, our RT measures suggested that phonological competitors remained at a higher level of activation after competition was resolved. As a result, they were ultimately processed faster as targets and the corresponding image was selected faster compared to when they were preceded by an unrelated prime. In sum, both the inhibitory and facilitatory phonological priming effects suggest that access to the bilingual lexicon is language-nonselective, and that words from both languages are co-activated.

In addition to CLI driven by phonological representations, our study also revealed CLI at the level of semantic representations. Children's behavior in the translation priming condition was in line with previous studies with bilingual toddlers (Floccia et al., 2020) and adults (e.g., Gollan et al., 1997): upon hearing a target word that was the translation of the prime, children looked towards the target image more than when prime and target were unrelated, and they selected the target image more quickly. This facilitatory priming suggests that translation equivalents share semantic representations, as assumed in various models (Dijkstra et al., 2019; Dijkstra & van Heuven, 2002; Shook & Marian, 2013). Consequently, when the semantic representation of a word is activated, words that share the same semantic representation (i.e., translation equivalents) are processed more quickly, resulting in facilitatory priming (see Figure 5, right panel).

In the phonological-priming-through-translation condition, we investigated interactions between phonological and semantic representations from both languages. We found that children's eye movements towards the target image decreased early in the trial, in the same way they did in the phonological priming condition. These similar patterns suggest similar processes: a prime word's translation equivalent becomes activated via the shared semantic representation, and subsequently competes with phonologically related words from both languages (Figure 5, bottom panel). As also argued by Von Holzen and Mani (2012), such effects are only possible across languages in truly language-nonselective word processing, allowing interactions between semantic and phonological representations from both

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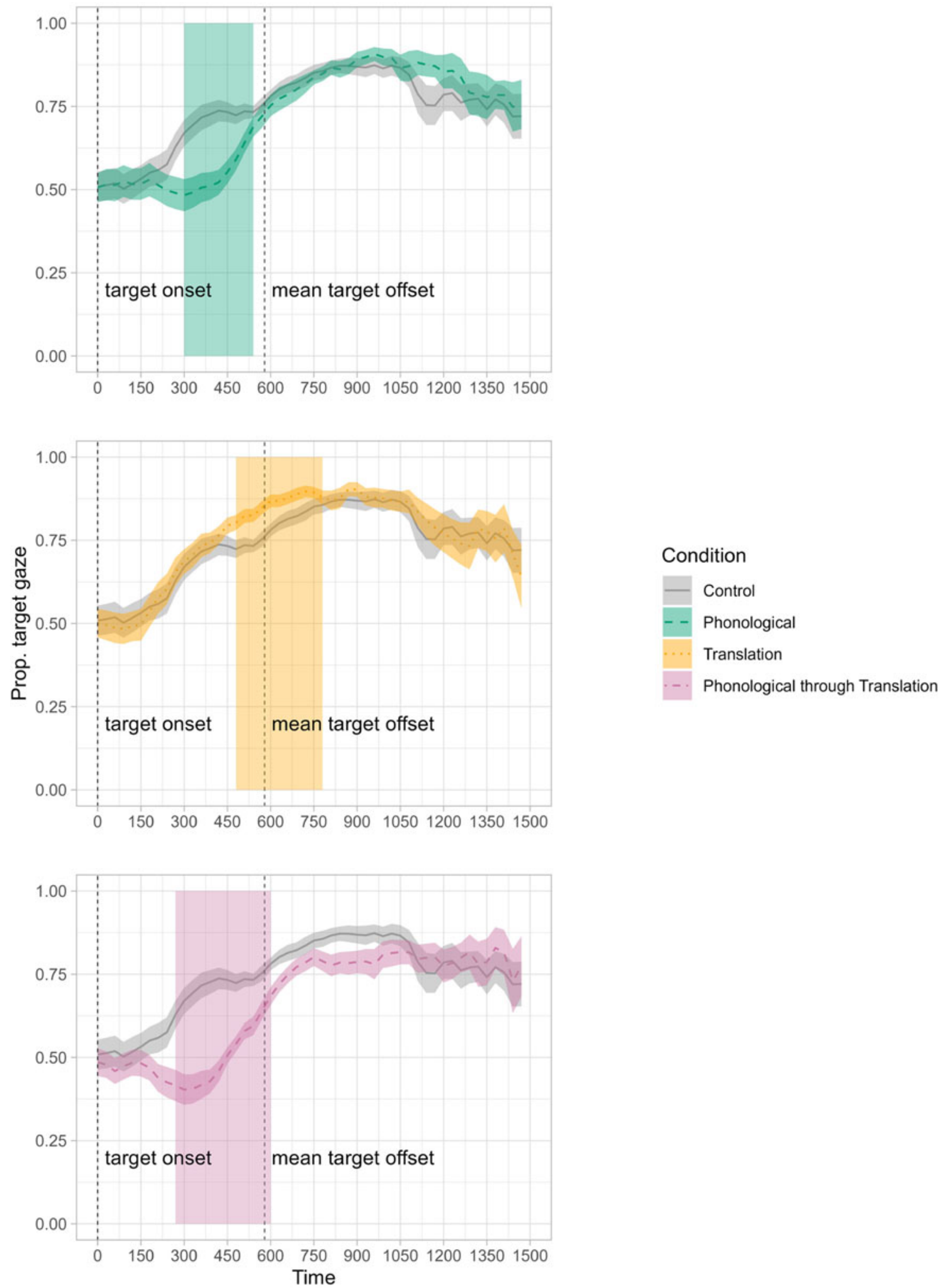

Figure 4. Proportion of children's gaze towards the target over time per condition.

languages. These interactions between semantic and phonological representations also play a role in translation priming: as activation feeds back from the activated semantic representation to the phonological representations of the prime as well as its translation, translation priming is mostly likely not only driven by the higher activation of the semantic representation, as discussed above, but also the phonological representation (Figure 5, right panel).

Unlike in phonological priming, there was no significant facilitatory effect of phonological priming through translation in children's RTs. Because there was a trend towards faster selection of

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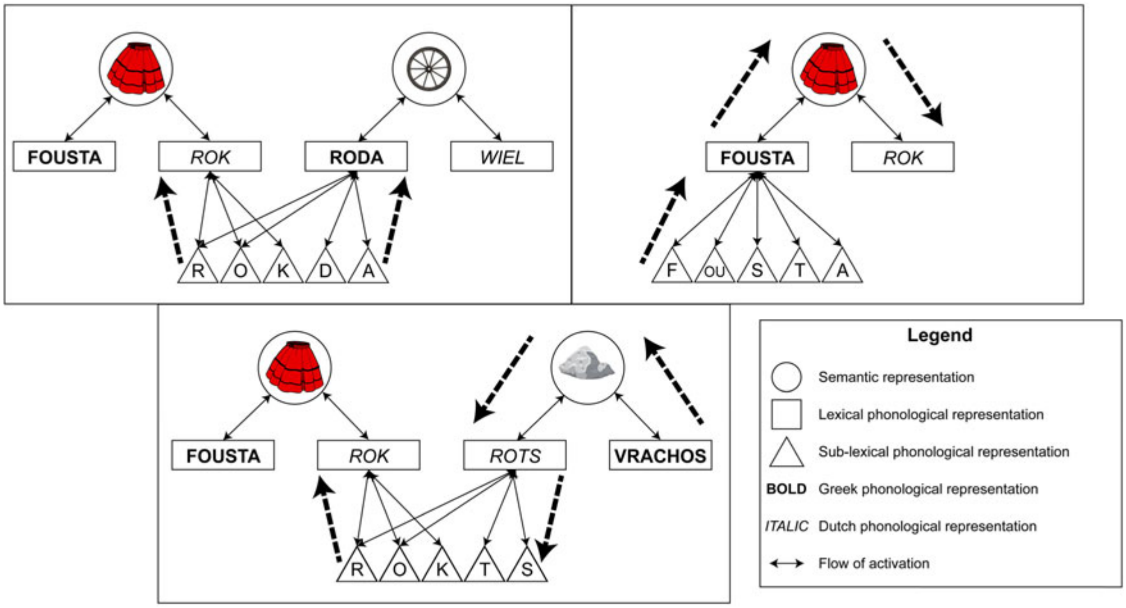

Figure 5. Processes of activation spreading and co-activation in the bilingual lexicon causing phonological priming between Greek prime *roda* "wheel" and Dutch target *rok* "skirt" (left), translation priming between Greek prime *fousta* "skirt" and Dutch target *rok* "skirt" (right), and phonological priming through translation from Greek prime *vrachos* "rock" - via Dutch *rots* "rock" - to Dutch target *rok* "skirt".

the target image (Table 3), it is likely that the phonological competitors were activated as in phonological priming, but to a lesser degree because of the indirect nature of this form of priming, which depends on activation spreading across multiple representations (Figure 5, bottom panel). This is supported by findings from Amrhein and Knupsky (2007), who found facilitatory effects of phonological priming through translation to be weaker than effects of phonological priming in bilingual adults.

In sum, the different types of priming effects found in this study are in line with studies on bilingual toddlers (Floccia et al., 2020; Jardak & Byers-Heinlein, 2019; Singh, 2014; Von Holzen & Mani, 2012) and with studies on bilingual adults (Amrhein & Knupsky, 2007; Basnight-Brown & Altarriba, 2007; Dijkstra, 2005; Dimitropoulou et al., 2011a, 2011b; Duyck & Warlop, 2009; Gollan et al., 1997; Jouravlev et al., 2014; Nakayama et al., 2012; van Hell & Tanner, 2012; Van Wijnendaele & Brysbaert, 2002). Using both eye-tracking and RT measures, the combined evidence from the present study and previous literature suggests that highly similar processes take place in bilinguals at different stages of development, in an integrated bilingual lexicon with shared semantic and sub-lexical phonological representations.

4.2. Language exposure

In addition to investigating CLI at multiple levels of representation in the lexicon, we examined the effects of relative language exposure. We found a main effect of language exposure in RTs, whereby children who received more Dutch exposure selected the target image faster than children who received less Dutch exposure. This suggests that exposure affects the resting-level activation of representations in the lexicon, in line with the BIA+ and Multilink models: for children who received more Dutch exposure, the Dutch target words had a higher resting-level activation and were therefore activated and processed more quickly by these children than by children who received less Dutch exposure. Contrary to our predictions, however, we did not find a relation between language exposure and priming effects – that is, effects of phonological priming, translation priming, and phonological priming through translation emerged regardless of children's relative exposure in our sample. Whilst the dominance effects we predicted are in line with the BIA+ and Multilink models and are often found in adult literature, previous child studies often did not find such effects either: to our knowledge, only Singh (2014) found effects of relative exposure in between-language priming in children. Floccia and colleagues (2020) did not find any effects, and neither did Jardak and Byers-Heinlein (2019), who, despite operationalizing language dominance in terms of vocabulary size,[5] related their hypotheses and findings to language exposure.

A lack of exposure effects on priming may be explained in different ways. First of all, there may be developmental differences. Combining explanations by Floccia and colleagues (2020) and Jardak and Byers-Heinlein (2019), it is possible that, in children, semantic representations are not shared between translation equivalents, but merely connected. According to Jardak and Byers-Heinlein (2019), the connection between these semantic representations is strengthened – leading to stronger priming effects – with increased exposure to the concepts. Because exposure to a concept may come from either language, translation priming would not be affected by relative language exposure. However, as discussed by Floccia and colleagues (2020), in the age group we examined, semantic representations of translation equivalents are most likely shared, as in adults. Hence, an explanation along the lines of Jardak and Byers-Heinlein (2019) seems unlikely. Furthermore, their account cannot explain our null findings for exposure in phonological priming, nor is it clear why we should still find a main effect of exposure in RTs.

Alternatively, as proposed by Floccia and colleagues (2020), there may be an influence of exposure on lexical priming that may become apparent under certain circumstances only, and this may depend on the diversity within participant samples. We aimed for a diverse sample, but within boundaries: all children lived in the Netherlands and attended Dutch schools. There was quite a range in how much Greek the children heard (15% – 69%), but on average they heard more Dutch than Greek (63%). The difference in resting-level activation between Dutch and Greek may have been greater than any differences between individual children's levels of activation in Greek, with the result that the former masked any differences in the latter.

Finally, the null results in most child studies so far may be an effect of smaller participant samples and generally noisier data compared to many adult studies. Much larger samples representing a large range in language exposure and/or proficiency would allow us to systematically and reliably investigate to what extent lexical CLI in bilingual children is affected by such individual differences. As collecting data from bilingual children often has many practical limitations, in practice this would be an opportunity for large-scale international collaborations between child bilingualism researchers, in line with the work of Visser and colleagues (2022) on infants.

5. Conclusion

The present study revealed cross-linguistic influence in the form of between-language priming effects in auditory lexical processing in four-to-nine-year-old simultaneous bilinguals with varying levels of language exposure, across multiple levels of representation in the lexicon. Using both eye-tracking and reaction times as measures for language processing in a picture selection task, we found between-language priming effects driven by phonological and semantic similarities, as well as indirect priming effects driven by interactions between phonology and semantics. Language exposure did not influence the strength of these priming effects, although it did affect overall processing speed.

Importantly, through our combination of language processing measures, it became evident that eye-tracking and reaction time measures tap into different aspects of lexical processing in which cross-linguistic influence occurs. We would recommend the use of multiple measures to fully understand processing during lexical priming in particular and word comprehension in general.

To our knowledge, this study is the first to investigate between-language priming in school-aged simultaneous bilingual children, considering both semantic and phonological representations as well as language exposure in one study. Altogether, these results provide evidence for an integrated bilingual lexicon in simultaneous bilingual children, fully shared at the levels of semantic and sub-lexical phonological representations, with a high degree of connectivity and interaction within and between these representations. Alongside evidence from studies with younger children and with adults, this shows that the lexicon of bilinguals is organized in a highly similar manner at earlier and later stages of development.

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Data availability statement. The data and analysis script used can be found on this project's entry on the Open Science Framework (link: https://osf.io/q4h28/) under a CC-By Attribution 4.0 International license.

Supplementary Material. For supplementary material accompanying this paper, visit https://doi.org/10.1017/S136672892300055X

Notes

1 Jardak and Byers-Heinlein (2019) used vocabulary rather than exposure as their measure of language dominance. To increase comparability with their study, we also repeated our analyses using a measure based on vocabulary rather than exposure. The overall results were the same (see Appendix A).

2 We made some exceptions for phonemes that were similar, such as /ɑ/ and /a/.

3 This large-scale database only includes Dutch words. For Greek primes, we used their Dutch translations to approximate their AoA. Although this does not account for phonological aspects that may affect word acquisition, semantic and cultural aspects are likely relatively well accounted for, as all children were growing up in the Netherlands.

4 As trial duration depended on RT, this time window was chosen to include the majority of the data (the end of the window corresponded approximately with the average RT + 1 SD) while discarding time bins with few observations.

5 To check whether inconsistencies among studies may stem from different operationalizations, we repeated our analyses with a proficiency measure rather than an exposure measure, but this did not change our most important outcomes (see Appendix A). Importantly, priming from Greek to Dutch was neither affected by children's Greek proficiency nor children's Greek exposure.

References

Alloway, T. P. (2012). *Alloway Working Memory Assessment 2 (AWMA-2)*. Pearson.

Amrhein, P., & Knupsky, A. (2007). Phonological facilitation through translation in a bilingual picture-Phonological facilitation through translation in a bilingual picture-naming task naming task. *Bilingualism: Language and Cognition*, *10*(3), 211–223. https://doi.org/10.1017/S1366728907003033

Baayen, R. H., & Milin, P. (2010). Analyzing reaction times. *International Journal of Psychological Research*, *3*(2), 12–28.

Basnight-Brown, D. M., & Altarriba, J. (2007). Differences in semantic and translation priming across languages: The role of language direction and language dominance. *Memory and Cognition*, *35*(5), 953–965. https://doi.org/10.3758/BF03193468

Bates, D., Mächler, M., Zurich, E., Bolker, B. M., & Walker, S. C. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(7), 1–48.

Brysbaert, M., Stevens, M., De Deyne, S., Voorspoels, W., & Storms, G. (2014). Norms of age of acquisition and concreteness for 30,000 Dutch words. *Acta Psychologica*, *150*, 80–84. https://doi.org/10.1016/J.ACTPSY.2014.04.010

Chaouch-Orozco, A., González Alonso, J., & Rothman, J. (2021). Individual differences in bilingual word recognition: The role of experiential factors and word frequency in cross-language lexical priming. *Applied Psycholinguistics*, *42*(2), 447–474. https://doi.org/10.1017/S014271642000082X

Dalmaijer, E., Mathôt, S., & van der Stigchel, S. (2014). PyGaze: An open-source, cross-platform toolbox for minimal-effort programming of eyetracking experiments. *Behavior Research Methods*, *46*, 913–921. https://doi.org/10.3758/s13428-013-0422-2

Dijkstra, T. (2005). Bilingual word recognition and lexical access. In J. F. Kroll & A. M. B. de Groot (Eds.), *Handbook of Bilingualism: Psycholinguistic Approaches* (pp. 179–201). Oxford University Press.

Dijkstra, T., & van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition*, *5*(3), 175–197. https://doi.org/10.1017/S1366728902003012

Dijkstra, T., Wahl, A., Buytenhuis, F., van Halem, N., Al-jibouri, Z., de Korte, M., & Rekké, S. (2019). Multilink: A computational model for bilingual word recognition and word translation. *Bilingualism: Language and Cognition*, *22*(4), 657–679. https://doi.org/10.1017/S1366728918000287

Dimitropoulou, M., Duñabeitia, J. A., Avilés, A., Corral, J., & Carreiras, M. (2010). Subtitle-Based Word Frequencies as the Best Estimate of Reading Behavior: The Case of Greek. *Frontiers in Psychology*, *1*, 218. https://doi.org/10.3389/FPSYG.2010.00218

Dimitropoulou, M., Duñabeitia, J. A., & Carreiras, M. (2011a). Phonology by itself: Masked phonological priming effects with and without orthographic overlap. *Journal of Cognitive Psychology*, *23*(2), 185–203. https://doi.org/10.1080/20445911.2011.477811

Dimitropoulou, M., Duñabeitia, J. A., & Carreiras, M. (2011b). Two words, one meaning: Evidence of automatic co-activation of translation equivalents. *Frontiers in Psychology*, *2*(AUG), 1–20. https://doi.org/10.3389/fpsyg.2011.00188

Dufour, S. (2008). Phonological priming in auditory word recognition: When both controlled and automatic processes are responsible for the effects. *Canadian Journal of Experimental Psychology*, *62*(1), 33–41. https://doi.org/10.1037/1196-1961.62.1.33

Dunn, L. M., Dunn, L. M., & Schlichting, J. E. P. T. (2005). *Peabody picture vocabulary test-III-NL*. Harcourt Test Publishers.

Duyck, W., & Warlop, N. (2009). Translation priming between the native language and a second language: New evidence from Dutch–French bilinguals. *Experimental Psychology*, *56*(3), 173–179. https://doi.org/://doi.org/10.1027/1618-3169.56.3.173

Floccia, C., Delle Luche, C., Lepadatu, I., Chow, J., Ratnage, P., & Plunkett, K. (2020). Translation equivalent and cross-language semantic priming in bilingual toddlers. *Journal of Memory and Language*, *112*. https://doi.org/10.1016/j.jml.2019.104086

Forbes, S., Dink, J., & Ferguson, B. (2021). *eyetrackingR* (R package version 0.2.0). http://www.eyetracking-r.com/

Fox, J., & Weisberg, S. (2019). *An R Companion to Applied Regression, Third Edition*. Sage.

Gollan, T. H., Forster, K. I., & Frost, R. (1997). Translation priming with different scripts: Masked priming with cognates and noncognates in Hebrew–English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(5), 1122–1139. https://psycnet.apa.org/fulltext/1997-06939-004.pdf

Haman, E., Łuniewska, M., & Pomiechowska, B. (2015). Designing cross-linguistic lexical tasks (CLTs) for bilingual preschool children. In S. Armon-Lotem, J. de Jong, & N. Meir (Eds.), *Assessing Multilingual Children: Disentangling Bilingualism From Language Impairment* (pp. 196–240). Multilingual Matters. https://doi.org/10.21832/9781783093137-010

Hermans, D., Bongaerts, T., de Bot, K., & Schreuder, R. (1998). Producing words in a foreign language: Can speakers prevent interference from their first language? *Bilingualism: Language and Cognition*, *1*(3), 213–229. https://doi.org/10.1017/S1366728998000364

Jardak, A., & Byers-Heinlein, K. (2019). Labels or Concepts? The Development of Semantic Networks in Bilingual Two-Year-Olds. *Child Development*, *90*(2), e212–e229. https://doi.org/10.1111/cdev.13050

Jouravlev, O., Lupker, S. J., & Jared, D. (2014). Cross-language phonological activation: Evidence from masked onset priming and ERPs. *Brain and Language*, *134*, 11–22. https://doi.org/10.1016/J.BANDL.2014.04.003

Kambanaros, M., Grohmann, K. K., & Michaelides, M. (2013). Lexical retrieval for nouns and verbs in typically developing bilectal children. *First Language*, *33*(2), 182–199. https://doi.org/10.1177/0142723713479435

Keuleers, E., Brysbaert, M., & New, B. (2010). SUBTLEX-NL: A new measure for Dutch word frequency based on film subtitles. *Behavior Research Methods*, *42*(3), 643–650. https://doi.org/10.3758/BRM.42.3.643

Lemhöfer, K., Dijkstra, T., Schriefers, H., Baayen, R. H., Grainger, J., & Zwitserlood, P. (2008). Native Language Influences on Word Recognition in a Second Language: A Megastudy. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*(1), 12–31. https://doi.org/10.1037/0278-7393.34.1.12

Lenth, R. V. (2022). *emmeans: Estimated Marginal Means, aka Least-Squares Means*. (R package version 1.7.2.). https://cran.r-project.org/package=emmeans

Mandera, P., Keuleers, E., & Brysbaert, M. (2017). Explaining human performance in psycholinguistic tasks with models of semantic similarity based on prediction and counting: A review and empirical validation. *Journal of Memory and Language*, *92*, 57–78. https://doi.org/10.1016/j.jml.2016.04.001

Marinis, T., & Armon-Lotem, S. (2015). Sentence Repetition. In S. Armon-Lotem, J. de Jong, & N. Meir (Eds.), *Assessing Multilingual Children: Disentangling Bilingualism from Language Impairment* (pp. 95–124). Multilingual Matters. https://doi.org/10.21832/9781783093137

Maris, E., & Oostenveld, R. (2007). Nonparametric statistical testing of EEG- and MEG-data. *Journal of Neuroscience Methods*, *164*(1), 177–190. https://doi.org/10.1016/J.JNEUMETH.2007.03.024

Mathôt, S., Schreij, D., & Theeuwes, J. (2012). OpenSesame: An open-source, graphical experiment builder for the social sciences. *Behavior Research Methods*, *44*, 314–324. https://doi.org/10.3758/S13428-011-0168-7

Mulder, F., Timman, Y., & Verhallen, S. (2009). *Handreiking bij de Basiswoordenlijst Amsterdamse Kleuters (BAK)*. ITTA.

Nakayama, M., Sears, C. R., Hino, Y., & Lupker, S. J. (2012). Cross-script phonological priming for Japanese–English bilinguals: Evidence for integrated phonological representations. *Language and Cognitive Processes*, *27*(10), 1563–1583. https://doi.org/10.1080/01690965.2011.606669

Poarch, G. J., & van Hell, J. G. (2012). Cross-language activation in children's speech production: Evidence from second language learners, bilinguals, and trilinguals. *Journal of Experimental Child Psychology*, *111*(3), 419–438. https://doi.org/10.1016/j.jecp.2011.09.008

R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.r-project.org/

Schaalje, G. B., McBride, J. B., & Fellingham, G. W. (2002). Adequacy of approximations to distributions of test statistics in complex mixed linear models. *Journal of Agricultural, Biological, and Environmental Statistics*, *7*(4), 512–524. https://doi.org/10.1198/108571102726

Schlichting, J. E. P. T., & Lutje Spelberg, H. C. (2002). *Lexilijst Nederlands: een instrument om de taalontwikkeling te onderzoeken bij Nederlandstalige kinderen van* 15-27 *maanden in het kader van vroegtijdige onderkenning*. Swets.

Shook, A., & Marian, V. (2013). The Bilingual Language Interaction Network for Comprehension of Speech. *Bilingualism: Language and Cognition*, *16*(2), 304–324. https://doi.org/10.1017/S1366728912000466

Singh, L. (2014). One World, Two Languages: Cross-Language Semantic Priming in Bilingual Toddlers. *Child Development*, *85*(2), 755–766. https://doi.org/10.1111/cdev.12133

Spivey, M. J., & Marian, V. (1999). Cross Talk Between Native and Second Languages: Partial Activation of an Irrelevant Lexicon. *Psychological Science*, *10*(3), 281–284.

Unsworth, S. (2013). Assessing the role of current and cumulative exposure in simultaneous bilingual acquisition: The case of Dutch gender. *Bilingualism, Language and Cognition*, *16*(1), 86–110. https://doi.org/10.1017/S1366728912000284

van Dijk, C., van Wonderen, E., Koutamanis, E., Kootstra, G. J., Dijkstra, T., & Unsworth, S. (2021). Cross-linguistic influence in simultaneous and early sequential bilingual children: a meta-analysis. *Journal of Child Language*, 1–33. https://doi.org/10.1017/S0305000921000337

van Hell, J. G., & Tanner, D. (2012). Second Language Proficiency and Cross-Language Lexical Activation. *Language Learning*, *62*(SUPPL. 2), 148–171. https://doi.org/10.1111/j.1467-9922.2012.00710.x

Van Wijnendaele, I., & Brysbaert, M. (2002). Visual word recognition in bilinguals: Phonological priming from the second to the first language. *Journal of Experimental Psychology: Human Perception and Performance*, *28*(3), 616–627. https://doi.org/https://doi.org/10.1037/0096-1523.28.3.616

van Wonderen, E., & Unsworth, S. (2021). Testing the validity of the Cross-Linguistic Lexical Task as a measure of language proficiency in bilingual children. *Journal of Child Language*, *48*, 1101–1125. https://doi.org/10.1017/S030500092000063X

Visser, I., Bergmann, C., Byers-Heinlein, K., Dal Ben, R., Duch, W., Forbes, S., Franchin, L., Frank, M. C., Geraci, A., Hamlin, J. K., Kaldy, Z., Kulke, L., Laverty, C., Lew-Williams, C., Mateu, V., Mayor, J., Moreau, D., Nomikou, I., Schuwerk, T., … Zettersten, M. (2022). Improving the generalizability of infant psychological research: The ManyBabies model. *Behavioral and Brain Sciences*, *45*. https://doi.org/10.1017/S0140525X21000455[Opens

Von Holzen, K., & Mani, N. (2012). Language nonselective access in bilingual toddlers. *Journal of Experimental Child Psychology*, *113*, 569–586. https://doi.org/10.1016/j.jecp.2010.09.011

Weber, A., & Cutler, A. (2004). Lexical competition in non-native spoken-word recognition. *Journal of Memory and Language*, *50*(1), 1–25. https://doi.org/10.1016/S0749-596X(03)00105-0

Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York. https://ggplot2.tidyverse.org

Zink, I., & Lejaegere, M. (2002). *N-CDIs: Lijsten voor communicatieve ontwikkeling*. Acco.

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