Journal of Experimental Child Psychology 221 (2022) 105443

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Cross-language activation during word recognition in child second-language learners and the role of executive function

Freya Gastmann [a], Gregory J. Poarch [b,*]

[a] Department of Language, Literature and Culture, TU Dortmund University, 44227 Dortmund, Germany
[b] Department of English Language & Culture, University of Groningen, 9712 EK Groningen, The Netherlands

ARTICLE INFO

Article history:
Received 8 July 2021
Revised 18 March 2022
Available online 24 May 2022

Keywords:
Bilingualism
Word recognition
Eye tracking
Cognates
Semantic relatedness
Executive function

ABSTRACT

We investigated lexical retrieval processes in 4- to 6-year-old German–English bilinguals by exploring cross-language activation during second-language (L2) word recognition of cognates and noncognates in semantically related and unrelated contexts in young learners of English. Both button presses (reaction times and accuracies) and eye-tracking data (percentage looks to target) yielded a significant cognate facilitation effect, indicating that the children's performance was boosted by cognate words. Nonetheless, the degree of phonological overlap of cognates did not modulate their performance. Moreover, a semantic interference effect was found in the children's eye movement data. However, in these young L2 learners, cognate status exerted a comparatively stronger impact on L2 word recognition than semantic relatedness. Finally, correlational analyses on the cognate and noncognate performance and the children's executive function yielded a significant positive correlation between noncognate performance and their inhibitory control, suggesting that noncognate processing depended to a greater extent on inhibitory control than cognate processing.

* Corresponding author at: Department of English Language & Culture, University of Groningen, The Netherlands.
E-mail address: g.j.poarch@rug.nl (G.J. Poarch).

https://doi.org/10.1016/j.jecp.2022.105443
0022-0965/

Introduction

Psycholinguistic research on bilingualism has focused on several questions pertaining to how speakers of more than one language navigate their languages during language production and comprehension, how they store and access words from several languages, and the relationship between language processing and cognition (Kroll et al., 2014). Because research on language processing in child second-language (L2) learners, in particular, can provide insight into the early bilingual lexicon, the current study examined the impact of native-language (L1) lexical information and conceptual representations on L2 word recognition in child L2 learners. Eye-tracking data was recorded using the visual world paradigm (Huettig et al., 2011) to gain insight into the participants' cognitive processing during word recognition. Moreover, it was examined whether individual differences in cognitive control modulated the children's performance.

Lexical–semantic representations in the bilingual lexicon

While accessing the mental lexicon, lexical information—including phonological, orthographical, and semantic representations—is retrieved (Dijkstra, 2005). Research on bilingual lexical processing has revealed that those retrieval processes are language nonselective, assuming a simultaneous coactivation of L1 and L2 (Kroll et al., 2014). This language nonselective view is also represented in two models that focus on lexical–semantic representations in bilinguals: Kroll and Stewart (1994) Revised Hierarchical Model (RHM), which illustrates language production in bilingual speakers, and the Bilingual Interactive Activation Plus (BIA+) model (Dijkstra & Van Heuven, 2002), which depicts the bilingual word recognition system.

The RHM suggests that lexical information is represented independently for each language, yet a conceptual system is shared. More precisely, it describes the mediation between L1 and L2 word forms through lexical links and access to the conceptual system through conceptual links. In the L1, conceptual representations are accessed directly, whereas in the L2, these representations are accessed via the L1 translation equivalent because the model assumes weaker L2-to-concept links in beginning L2 learners. However, the more proficient an L2 speaker becomes, the more the L2 word-to-concept links are strengthened. Therefore, the strength of lexical and conceptual links depends largely on L2 proficiency. The assumptions of the RHM have been confirmed in studies with adults (Kroll et al., 2002) and children (Poarch et al., 2015).

The BIA+ model (Dijkstra & Van Heuven, 2002) proposes that presenting a word orthographically in one language leads to coactivation of numerous similar word candidates in both languages. Word candidates are activated not only at their orthographic level but also at their corresponding phonological nodes, which then activate semantic nodes. Orthographical and phonological representations from both languages compete until a decision for the respective language has been made. Although the BIA+ models bilingual visual word recognition, the authors stressed its validity for bilingual auditory word recognition because, similar to orthographic input, auditory input also activates other word candidates.

A means to assess how meaning is linked to lexical representations is the exploration of semantic interference during language processing. A *semantic interference effect* (SIE) occurs when semantically related items are processed differently from semantically unrelated stimuli in an experimental task. Various studies have demonstrated such effects: In a visual world experiment, Dahan and Tanenhaus (2004) revealed an effect of semantic context in L1 spoken word recognition in adults. In a recent study by Vales and Fisher (2019), children heard an L1 word, subsequently looked at an array of pictures, and then needed to indicate whether the named item was present or not. The children showed longer reaction times for trials with related distractors relative to trials with unrelated distractors, demonstrating an SIE. Relatedly, Poarch et al. (2015) examined the interference of meaning in language processing in beginning child L2 learners. The study explored whether access of word meaning in early L2 learners relied more on lexical or conceptual mediation. The results of a translation production task supported the assumptions of the RHM, indicating lexical mediation in backward translation (from L2 to L1) and conceptual mediation in forward translation (from L1 to L2). Thus, beginning L2 learners were more likely to process words via the lexical route when translating L2 items to L1. In a subsequent translation recognition task, however, the children were influenced by the semantic manipulation in an L2 context given that they performed faster and more accurately in the semantically unrelated condition than in the semantically related condition. These results indicate that even learners at early stages of L2 acquisition can access meaning directly from the L2 word form. Poarch and colleagues pointed to differences in L2 learning contexts (see Comesaña et al., 2009) and/or task demands (production vs. comprehension) as an explanation for such early conceptual mediation.

Cross-language similarity of cognates

A word type that has frequently been used to investigate lexical coactivation is cognates. Cognates represent translation equivalents that share meaning and are phonologically and orthographically similar or identical across two or more languages (e.g., English *fish* /fɪʃ/ and German *Fisch* /fɪʃ/). Noncognates, in contrast, are translation equivalents that show no such overlap (e.g., English *dog* /dɔ:g/ and German *Hund* /hʊnt/). If processing cognates differ from processing noncognates, it can be regarded as evidence for coactivation of different languages (Dijkstra et al., 2010). Hence, cognates being processed faster and more accurately than noncognates is referred to as a *cognate facilitation effect* (CFE), indicating that phonological and/or orthographical representations have become activated in both target and nontarget languages (Poarch & Van Hell, 2012). Thus, cross-linguistic form overlap boosts lexical retrieval of cognates due to dual-language activation of lexical representations. This overlap enables faster recognition of such items and has been found to boost form-to-meaning mapping in both languages of bilingual children (Schelletter, 2002) and to facilitate word recognition in bilinguals (Méndez Pérez et al., 2010). This view is supported by the BIA+ model (Dijkstra & Van Heuven, 2002), which assumes that for cognate recognition both L1 and L2 words are activated by linguistic input due to their form overlap and in turn coactivate their shared semantic representation (for alternative views on the CFE, see, e.g., Costa et al., 2005). Because meaning is activated from both lexical representations, it is accessed faster compared with activation from only one lexical node. Noncognates, in contrast, induce less activation. Hence, L1 knowledge cannot facilitate processing as it does with cognates. With regard to the RHM (Kroll & Stewart, 1994), the retrieval of meaning of L2 words is mediated via the L1 translation equivalent. For cognate words, thus, access to meaning via the L1 would be facilitated due to the translation equivalents' form overlap. Noncognates, in contrast, would not experience such a form overlap boost (see also Casaponsa et al., 2015).

The CFE has been found in adult bilingual speakers in both production tasks (Poarch & Van Hell, 2014) and comprehension tasks (Van Hell & Dijkstra, 2002) and has also been observed in bilingual children for language production (Poarch & Van Hell, 2012) and language comprehension (Brenders et al., 2011). In addition, some studies have shown a gradual CFE depending on the extent of overlap between word pairs (Bosma et al., 2019; Dijkstra et al., 2010). Von Holzen et al. (2019) examined the impact of cross-linguistic similarity in monolingual and bilingual toddlers' word recognition, focusing on the degree of translation equivalents' phonological overlap. The results showed a CFE for L2 but not L1 word recognition. In addition, the CFE for L2 words increased with greater phonological overlap. The difference between L1 and L2 processing was ascribed to a dissimilarity of the children's L1 and L2 proficiency. L2 translation equivalents were not as profoundly established as their L1 counterparts, resulting in L2 words not affecting L1 processing in contrast to the opposite direction.

In a recent study, Floccia et al. (2020) examined cross-language activation in spoken word recognition by comparing translation equivalent priming (Experiment 1) and cross-linguistic semantic priming (Experiment 2) in bilingual toddlers. They found priming effects from both translation equivalent and cross-language semantic priming; however, contrary to their predictions (i.e., translation priming would be stronger than semantic priming; see Basnight-Brown & Altarriba, 2007, for such findings in adults), both effects were similar. Critically, in Experiment 2 cognate status did not modulate the children's performance, which contrasts with results from studies with children (Von Holzen et al., 2019).

Inhibitory control as a subdomain of executive function

Besides similarity effects within language and across language, other factors, such as cognitive differences among bilinguals, can facilitate or impede bilingual language processing. One cognitive mechanism of interest in psycholinguistic research has been how speakers control information that enters the cognitive system. This cognitive control mechanism can be summarized under the term *executive function* (EF), which is an umbrella term that comprises different cognitive processes and has been subdivided into three different functions: (a) updating and monitoring information entering working memory, (b) shifting attention between different tasks, and (c) inhibiting conflicting information (Miyake & Friedman, 2012).

These cognitive control mechanisms described by Miyake and Friedman (2012) also play a role in bilingual language processing. Because bilinguals face constant across-language competition during linguistic processing that needs to be resolved, they are assumed to rely on EF in shifting their attention, monitoring language input and output, and inhibiting misleading and/or irrelevant information (Poarch, 2018). More specifically, this mechanism serves to inhibit competing word candidates from the language not in use to successfully process the target input. Accordingly, Green (1998) proposed the inhibitory control model (IC model), which describes how bilinguals inhibit potential competitors from the nontarget language for successful target language processing. Although the BIA+ model does not include inhibitory control as a component of bilingual language comprehension, several studies have supported Green's model, suggesting that inhibitory control does in fact modulate cross-language competition in L2 learners and bilinguals during language comprehension. Particularly those individuals with more efficient EF show reduced cross-language activation compared with individuals with less efficient EF (see Mercier et al., 2014, for spoken word recognition; see Pivneva et al., 2014, for L2 sentence reading). Similarly, studies on bilingual language comprehension using code switching have found that cross-linguistic competition triggered enhanced cognitive control mechanisms (Bosma & Pablos, 2020).

Inhibitory control has been investigated by using nonlinguistic tasks such as the Flanker task (Eriksen & Eriksen, 1974), which induces cognitive conflict that needs to be resolved. Inhibitory control is measured by assessing the reaction times to trials in congruent and incongruent conditions, the latter requiring participants to suppress interference from misleading information (but see Poarch & Van Hell, 2019, for a discussion of the convergent validity of such EF tasks in bilingualism research). If participants show an overall higher processing speed in both conditions compared with other participants, this demonstrates an overall monitoring advantage. The difference score, calculated by subtracting reaction times in the congruent condition from those in the incongruent condition, provides information about the efficacy of inhibitory control. A larger difference score indicates more difficulty in controlling interference and resolving cognitive conflict. Thus, participants with smaller differences are assumed to have better inhibitory control (Poarch, 2018).

The current study

Although various studies have focused on cognate versus noncognate word recognition in children to assess orthographic and phonological cross-language representations, and others have examined semantic interference in L2 processing in comprehension, few (if any) have investigated bilingual word recognition in children focusing on phonological language coactivation while also adding the level of semantic conceptualization in the L2. To fill this gap, we aimed to explore L1 influence on L2 word recognition focusing on the phonological representations of the stimuli in the context of semantically related or unrelated competitors.

The following predictions regarding the impact of cognate status and semantic relatedness on children's L2 word recognition were made. First, the children would process cognates faster than noncognates, thereby showing a CFE. Second, cognates with greater phonological overlap would be processed faster than cognates with less overlap (Bosma et al., 2019; Von Holzen et al., 2019). Third, with regard to the semantic relatedness of the target and competitor picture, children would process stimuli with a semantically related competitor picture more slowly than in the unrelated condition (i.e., show an SIE; Poarch et al., 2015; Vales & Fisher, 2019). Fourth, furthermore, cognate status and semantic

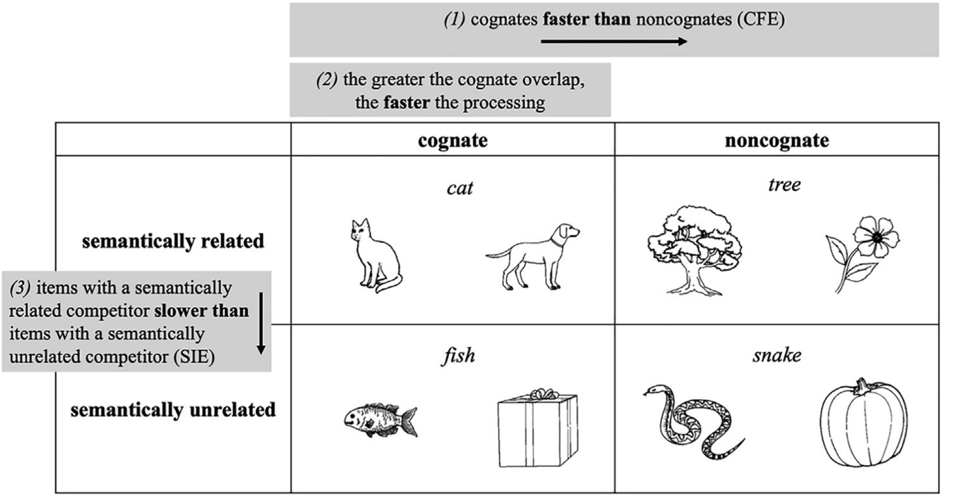

Fig. 1. Predictions for the word recognition task with stimulus examples. Italic words represent the auditory stimuli. In each sample condition, the left picture represents the target and the right picture represents the competitor.

relatedness were predicted to interact and modulate performance differently based on their combination. More specifically, cognate items presented with a semantically unrelated competitor should facilitate processing the most, whereas noncognate items presented with a semantically related competitor should facilitate processing the least (see Fig. 1 for an exemplary overview of conditions). Fifth, building on Poarch (2013; see General Discussion section), we predicted that speed of processing of cognates and noncognates would be differently modulated by participants' inhibitory control (as indexed by the Flanker difference score), with noncognates being more sensitive to inhibitory control than cognates.

Method

Participants

The participants were 30 4- to 6-year-old children from a bilingual German–English immersion kindergarten. Seven children were excluded from further analysis due to additional home exposure to English ($n = 4$) or a Flanker accuracy score below 50% ($n = 3$). The remaining 23 children spoke L1 German and L2 English. Four children were raised bilingually and also spoke Albanian, Georgian, Polish, or Spanish at home. The children received similar German and English input in the kindergarten, with the teachers speaking either German or English according to the "one person, one language" principle (Ronjat, 1913).

Parents provided signed consent[1] and completed a background questionnaire based on the Language and Social Background Questionnaire (LSBQ; Anderson et al., 2018) that included the parents' educational levels as a proxy for socioeconomic status (SES). The children's language proficiencies in understanding and speaking were assessed by parents and teachers, and ratings were collapsed. Means and standard deviations are presented in Table 1.

[1] There is no ethics committee available for experimental studies conducted with human participants at the Faculty of Philology, University of Münster. The current study is in accordance with local legislation and the institutional requirements and follows the code of ethics ("rules of good scientific practice") of the University of Münster. (2002) (2002) (2002) and The European Code of Conduct for Research Integrity (European Federation of Academies of Sciences and Humanities, 2017).

Table 1
Participants' background measures ($n = 23$).

	M	*SD*	Minimum	Maximum
Age (years)	5.7	0.7	4.4	6.7
Length of English immersion	3.1	1.3	0.8	4.8
Age of English acquisition (years)	2.6	1.3	1.0	5.8
Receptive German skills[a]	10.0	0.1	9.5	10.0
Productive German skills[a]	9.8	0.4	9.0	10.0
Receptive English skills[a]	5.7	0.9	4.0	7.5
Productive English skills[a]	4.1	1.0	2.0	6.0
Parents' education[b]	4.0	0.6	3.0	5.0

[a] Language proficiency on a 10-point scale from 1 (*hardly any*) to 10 (*very good*) proficiency.
[b] Parents' level of education on a 5-point scale (1 = *no school-leaving qualification,* 2 = *secondary school diploma,* 3 = *high school diploma,* 4 = *university degree,* 5 = *doctoral degree*) collapsed across both parents.

Table 2
Stimuli characteristics.

	Cognates		Noncognates		*t* Test
Number of letters	4.9	(1.4)	4.8	(1.5)	$t(78) = 0.3$, $p = .76$
Number of syllables	1.5	(0.7)	1.3	(0.5)	$t(78) = 1.5$, $p = .15$
SUBTLEX-US	3.3	(0.6)	3.3	(0.5)	$t(78) = -0.2$, $p = .88$
Zipf value	4.6	(0.6)	4.6	(0.5)	$t(78) = -0.2$, $p = .88$
Name agreement	1.0	(0.1)	0.9	(0.1)	$t(78) = 1.7$, $p = .09$
Visual complexity	17,975	(11566)	15,756	(5904)	$t(78) = 1.1$, $p = .28$
Age of acquisition	4.1	(1.1)	4.0	(0.7)	$t(78) = 0.5$, $p = .60$

Note. Standard deviations are in parentheses.

Stimuli

A total of 80 English word stimuli were selected, consisting of 40 German–English cognates and 40 German–English noncognates that were familiar to the children based on the assessment of their English-speaking kindergarten teacher. The English target words were matched across conditions on frequency (SUBTLEX-US database: Brysbaert & New, 2009; Zipf scale: Van Heuven et al., 2014), word length as measured by number of syllables and letters, name agreement, visual complexity, and age of acquisition (Kuperman et al., 2012). Stimuli characteristics are listed in Table 2. The words were recorded by a female native speaker of English. In addition, to explore the impact of degree of cognate word overlap on word recognition, phonological overlap of the German–English cognate word pairs was measured using the phonological Levenshtein distance (LD; Levenshtein, 1966; $M = 0.7$, $SD = 0.2$). The LD considers any insertions, deletions, and substitutions that need to be made to edit one word string into the other and is relative to word length (Schepens et al., 2013). To calculate LDs, IPA (International Phonetic Alphabet) transcriptions of the English recordings were compared to the Standard German pronunciation of their translation equivalents (Kleiner & Knöbl, 2015). For the current study, orthographic LDs were not measured because the children were preliterate and orthographical overlap would have had no impact on their performance.

Each word stimulus was presented with its matching picture and a competitor picture that was either semantically related or unrelated to the target image.[2] Target and competitor pictures were defined as areas of interest (AoIs) to allow for a measurement of target/competitor fixations. All pictures were black-and-white drawings selected from the International Picture Naming Project database

[2] We thank a reviewer for highlighting the need to reflect on our measure to determine the semantic relatedness of target and competitor pictures. Consequently, a post hoc norming study was run to assess whether semantic relatedness was indeed significantly higher for the related word pairs compared to the unrelated ones. The results of a *t* test confirmed this assumption, $t(158) = 31.20$, $p < .001$.

(Szekely et al., 2004). Competitor images consisted of 80 noncognate stimuli. Four items with similar characteristics as the stimuli words were chosen for practice trials. The stimuli are available in the online supplementary material.

Experimental design

A 2 (Cognate Status of Target Word: cognate vs. noncognate) × 2 (Semantic Relatedness of Competitor Picture: semantically related vs. unrelated) factorial design was used.

Procedure

The experiment was programmed in SMI Experiment Center and run on a laptop (HP ZBook 15 G2) with a 15.6-inch display. Participants' eye movements were recorded using an SMI RED250mobile eye tracker attached to the bottom of the laptop's screen. Key presses were logged on an additional keyboard attached to the laptop via a USB port.

The children performed a word recognition task for which no verbal response was required and were tested by the experimenter individually in a quiet room at their kindergarten. The experimenter paid visits to the kindergarten prior to conducting the study so that the children became familiar with her. During the task, which took about 20 min, the children were seated approximately 60 cm from the screen and heard the auditory stimuli through headphones. When the experiment instructions were explained, the children were addressed in German to ensure their understanding of the task. Before starting the experiment, an eye-tracking calibration and validation were run, and 4 test trials were introduced to the children in English to ensure that they were familiarized with the task and to induce an English language mode. The children were not informed about the goal of the study, and after completing the experiment the children received a small gift for their participation.

During the experiment, the participants saw 80 trials in total (20 trials per condition). The experiment was set up in four 20-trial blocks. Between each block, a validation was run to ensure correct recording of eye movements. Each trial began with a preview, a simultaneous presentation of both target and competitor images for 1500 ms. After this time had elapsed, the auditory stimulus of the target picture was presented, and the images remained on-screen for another 3000 ms. After 4500 ms, each trial ended and was followed automatically by either the next trial or a validation. The presentation of stimuli was randomized across all 80 trials, as was the location (left vs. right) at which target and competitor images were displayed on-screen (see Von Holzen et al., 2019). In addition, participants saw the target–competitor pairs equally often and counterbalanced in semantically related and unrelated conditions. The children needed to decide which of the two pictures displayed on the screen matched the previously heard auditory stimulus by pressing one of two keyboard keys. The participants were asked to respond as accurately and quickly as possible.

In a second session a week later, the children completed a Flanker task, which was run in E-Prime (Schneider et al., 2002), to measure their nonverbal EF. For the purpose of this study, a children's version with arrays of five fish instead of arrows was used (Jäger et al., 2014). The children needed to indicate the direction of the target fish (looking left or right) in the middle of the array by pressing one of two keys on the keyboard. The direction of the target fish was presented either as a congruent trial (with flanking fish pointing in the same direction as the target fish) or as an incongruent trial (with the target fish pointing in the opposite direction than the flanking fish). There were 120 trials in total (60 congruent trials and 60 incongruent trials) that were randomly displayed and preceded by 20 neutral test trials. The stimuli were presented for 3000 ms or until the participants pressed a key. Incorrect key presses and reaction times (RTs) under 200 ms were excluded from the RT analysis (congruent = 12.0%; incongruent = 22.9%). A Flanker effect indicating the magnitude of the participants' inhibitory control was calculated by subtracting congruent RTs from incongruent RTs.

Analysis

The results of the word recognition experiment (i.e., accuracies of the button presses, RTs, and eye movements) were exported with SMI BeGaze software (Version 3.7). Mean RTs and mean accuracy rates were calculated for the overall conditions and their factorial crossings. Incorrect button presses and responses that were faster than 500 ms (cognate related = 3.0%, cognate unrelated = 3.7%, noncognate related = 14.4%. and noncognate unrelated = 12.0%) or that had not been made within 3000 ms after auditory stimulus onset were omitted from the RT analysis (cognate related = 3.7%, cognate unrelated = 2.4%, noncognate related = 12.0%, and noncognate unrelated = 11.5%).

Linear mixed-effects analyses were performed on RTs of the correct button presses and accuracy rates. With the aid of the "lme4" package (Bates et al., 2015) for the statistical software R (R Core Team, 2019), RTs were analyzed using linear mixed-effects (LME) models and accuracies using generalized linear mixed-effects (GLME) models with cognate status and semantic relatedness as fixed effects and with participants and stimuli as random effects. A likelihood ratio test was performed using the *anova()* function to assess the statistical significance of the linear models. In addition to analyzing the impact of phonological overlap of cognate words as fixed effects in the models, the impact of the children's background measures on their performance was also assessed using age, age of acquisition (AoA), length of immersion (LoI), English proficiency, and SES as fixed effects.

Using the R package "eyetrackingR" (Dink & Ferguson, 2018), the proportion of time during which the children looked at the target or the competitor picture was calculated. Non-AoI looks (neither target nor competitor) were treated as missing, and trials with more than 50% track loss (i.e., when the eye tracker loses track of participants' eye movements due to blinking) were removed from analysis. This resulted in 177 trials being excluded (cognate related = 46, cognate unrelated = 46, noncognate related = 51, and noncognate unrelated = 34). Analyses focused on the post-naming phase, the time window after onset of the auditory stimulus (1500–4500 ms). For each participant, mean proportion of target looks for cognates/noncognates and semantically related/unrelated stimuli were calculated for time bins of 100 ms. An LME analysis was run with Elog (the empirical logit transformation, calculated in the eyetrackingR package to analyze eye-tracking data) as dependent variable, cognate status and semantic relatedness as fixed effects, and participants and trials as random effects to predict the children's target fixations based on the condition of each trial.

In addition, a nonparametric permutation analysis (Delle Luche et al., 2015; Maris & Oostenveld, 2007; Von Holzen et al., 2019) for target fixations for cognates and noncognates was performed using *t* tests to determine the time clusters in which significant differences between the conditions did not appear by chance. The time clusters were then randomized with a sample size of 1000 and compared to a Monte Carlo *p* value.

Following Mirman et al.'s (2008) approach applying growth curve analysis (GCA) to eye-tracking data, a GCA was subsequently performed on the participants' target looks in the post-naming phase to provide more detailed insight into cognitive processing. Instead of only defining mean proportions of target looks, a GCA describes the shapes of target fixation curves and sheds light on the change in processing over time. Note that Huang and Snedeker (2020) have identified limitations of GCA; for current purposes, however, it was deemed a fitting instrument to assess changes in the children's fixation proportions over time. Although previous studies on children's word recognition have used smaller time windows of 1500 ms (Law & Edwards, 2015) and 2000 ms (Von Holzen et al., 2019), in this study the target looks in the entire post-naming phase (3000 ms) were examined to grasp interindividual variation in performance irrespective of the children's button presses. To perform the GCA, target looks were analyzed with a mixed-effects model including cognate status and semantic relatedness as fixed effects. To determine the rise and fall in target looks more precisely, orthogonal polynomials of the first (linear) order and second (quadratic) order were included in the analysis (Law & Edwards, 2015; Von Holzen et al., 2019). The linear time term reflects the rate at which looks to the target increase, and the quadratic one resembles the modality of the curve with its rise and fall. Because the fixation curves in the cognate/noncognate condition and in the semantically related/unrelated condition bent only once, orthogonal polynomials beyond the second order were disregarded. Participant and participant-by-cognate status were included in the model as random effects.

Finally, RT performance for the cognate and noncognate conditions was entered into a correlational analysis with the Flanker results.

Results

Behavioral data

For RTs, the LME analysis and likelihood ratio test yielded that cognate status affected RTs significantly, $\chi^2(1) = 19.63$, $p < .001$, speeding up cognate processing by 170 ± 36.9 ms. Semantic relatedness showed no effect on children's RTs, $\chi^2(1) = 2.68$, $p = .10$, nor was there a significant interaction between the two factors, $\chi^2(1) = 0.33$, $p = .57$. For accuracies, the GLME analysis and likelihood ratio test revealed a significant main effect of cognate status, $\chi^2(1) = 23.15$, $p < .001$, no effect of semantic relatedness, $\chi^2(1) = 0.58$, $p = .45$, and no interaction, $\chi^2(1) = 0.99$, $p = .32$. In sum, cognates were processed faster and more accurately (1524 ± 0.94 ms) than noncognates (1691 ± 0.74 ms). However, semantic relatedness of the competitor picture did not influence speed and accuracy of word recognition. RT and accuracy data are presented in Tables 3 and 4.

Subsequently, an LME model with RTs predicted by phonological overlap of cognate words revealed no significant effect ($\beta = -82.96$, $SE = 68.73$), $t(864) = -1.21$, $p = .24$, indicating that cognate RTs were not modulated by degree of phonological overlap. A GLME model also yielded no such effect on cognate accuracies ($\beta = 0.72$, $SE = 1.14$), $z(895) = 0.63$, $p = .53$.

In addition, to assess whether any of the background measures affected the children's word recognition performance, LME models for RTs were performed with the participants' background measures as fixed effects. Whereas there was no interaction between RTs and age, AoA, LoI, or SES, the analysis with RTs predicted by English proficiency revealed a marginally significant effect ($\beta = -71.01$, $SE = 36.98$), $t(1538) = -1.92$, $p = .069$. The GLME models with accuracies yielded no interactions with age, AoA, SES, or English proficiency, but they did yield a significant effect for accuracies predicted by LoI ($\beta = 0.25$, $SE = 0.11$), $z(1687) = 2.28$, $p = .023$.

Eye-tracking data

Fig. 2 shows target fixation proportions as time sequence data with 100-ms time bins for cognate and noncognate items (Panel A) and for semantically related and unrelated condition items (Panel B).

Table 3
Reaction times (in milliseconds) and accuracies (proportions) by cognate status and semantic manipulation.

	Reaction time (ms)		Accuracy (proportion)	
Cognate	1524	(150)	.94	(.05)
Noncognate	1691	(152)	.74	(.14)
Cognate facilitation effect[a]	167		.12	
Related	1613	(140)	.83	(.09)
Unrelated	1601	(161)	.85	(.11)
Semantic interference effect[a]	12		.01	

Note. Standard deviations are in parentheses.
[a] Effects are calculated for reaction times and accuracies as the difference between both respective conditions.

Table 4
Mean reaction times (in milliseconds) and accuracies (proportions) for factorial crossing of cognate status with semantic relatedness.

	Reaction time (ms)		Accuracy (proportion)	
Cognate				
Related	1541	(163)	.94	(.06)
Unrelated	1506	(151)	.94	(.08)
Noncognate				
Related	1686	(144)	.73	(.15)
Unrelated	1696	(206)	.74	(.20)

Note. Standard deviations are in parentheses.

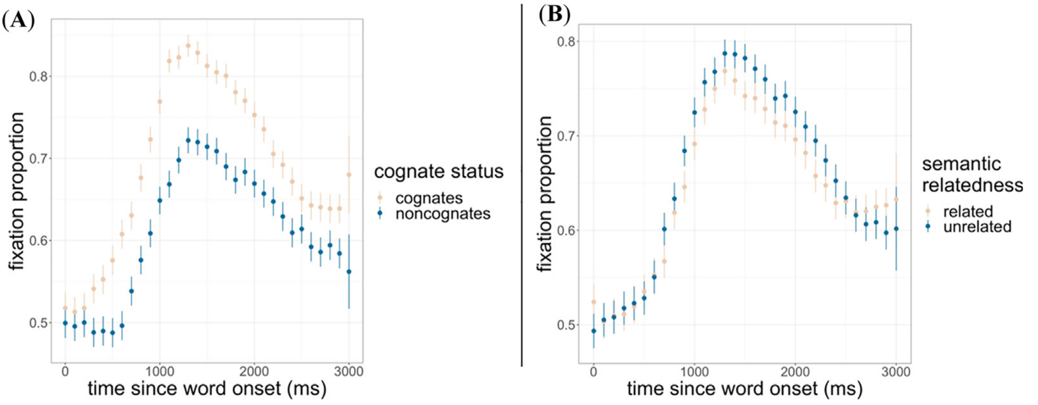

Fig. 2. Target fixation proportions for cognates and noncognates (A) and semantically related and unrelated items (B) for 100-ms time bins in the post-naming phase.

The graphs visualize a target fixation rate of approximately 50% at auditory stimulus onset, indicating that, overall, there was no looking preference for target or competitors before auditory stimulus onset. With the peak of target fixation curves residing at the 1300-ms time bin for cognates and noncognates as well as semantically related and unrelated items ($M = 0.78$, $SD = 0.11$), the eye-tracking data reveal that the children looked at the target faster than they were able to press a button (see Tables 3 and 4). The subsequent decrease of target fixation proportions can be ascribed to the fact that the children started looking elsewhere after their decision via a button press.

The LME model of the post-naming phase revealed a significant cognate effect ($p < .001$) and a marginally significant semantic effect ($p = .067$), but no interaction ($p = .96$). These findings indicate that, over the time course, target fixations increased significantly for cognate words compared to noncognate words and increased marginally significantly in the unrelated condition compared to the related condition.

A nonparametric permutation analysis of cognate status showed that at 300 ms after auditory stimulus onset, target looks quickly increased, and target fixation proportions for cognates differed from noncognates from 300 to 2600 ms ($p < .001$; see Fig. 3). Over the trial, target looks increased at a faster rate for cognates than for noncognates. The nonparametric permutation analysis for semantic relatedness was not significant.

Subsequently, a GCA was performed. Participant-by-cognate status was used as random effect given the previously found significant main effect of cognate status. The model's output is presented in Table 5 and Fig. 4. The results show that mean looks to the target were significantly higher for cognates than for noncognates ($p < .001$) and were significantly lower for words presented with a semantically related competitor than for words presented with an unrelated one ($p = .001$). The two-way interaction between the linear time term and semantic relatedness shows a marginally significantly slower rate for target looks in the related compared to the unrelated condition ($p = .08$). The two-way interaction between the quadratic time term and cognate status shows a significant effect of cognate status ($p = .001$), resulting in a steeper, more convex rise and fall in target looks for cognates compared to noncognates. The three-way interaction among the linear time term, semantic relatedness, and cognate status revealed a significant interaction ($p = .006$), indicating a faster rate of target looks for cognates presented with semantically unrelated competitors. Similarly, the three-way interaction among the quadratic time term, semantic relatedness, and cognate status yielded a significant interaction ($p = .029$), showing a steeper and more convex curve for target looks to cognates presented with unrelated competitors.

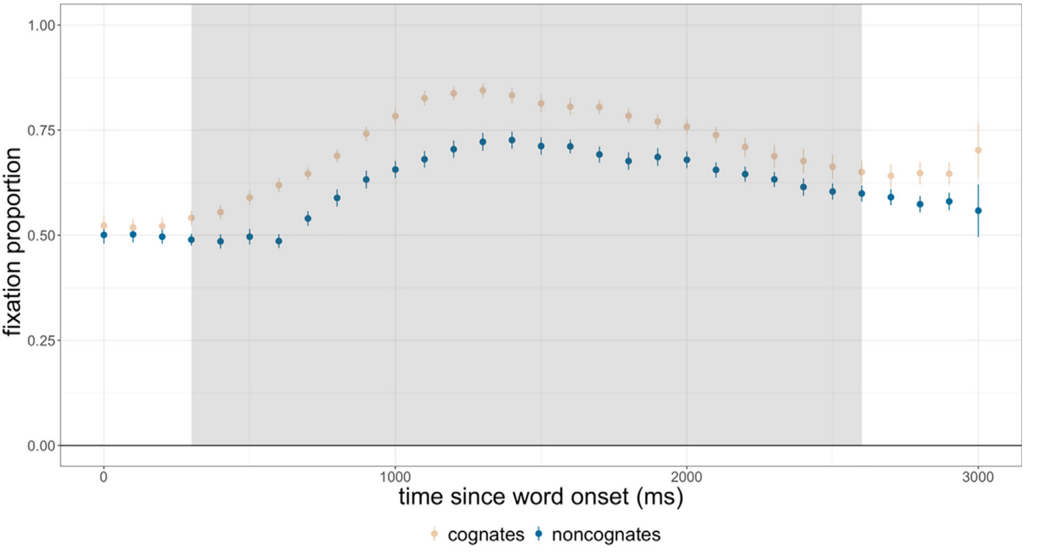

Fig. 3. Target fixation proportions for cognates and noncognates in the post-naming phase. The gray time window indicates a significant ($p < .001$) difference between conditions.

Table 5
Output of the mixed-effects model for target looks.

Fixed effect	*Estimate*	*SE*	*df*	*t*	*Pr*(>|*t*|)
(Intercept)	6.16	9.94	5.03	62.01	.000***
Linear	2.16	5.36	4.49	4.02	.000***
Quadratic	−3.65	5.13	5.14	−7.12	.000***
Semantic_relatedness	−1.99	6.11	4.57	−3.25	.001**
Cognate_status	7.26	1.18	3.07	6.17	.000***
Linear:Semantic_relatedness	−6.17	3.52	4.57	−1.75	.080+
Quadratic:Semantic_relatedness	4.15	3.58	4.57	1.16	.247
Linear:Cognate_status	−9.02	5.52	3.57	−1.63	.111
Quadratic:Cognate_status	−2.15	5.95	3.32	−3.61	.001**
Semantic_relatedness:Cognate_status	1.25	8.68	4.57	1.44	.151
Linear:Semantic_relatedness:Cognate_status	1.36	4.99	4.57	2.73	.006**
Quadratic:Semantic_relatedness:Cognate_status	1.11	5.10	4.57	2.18	.029*

+ $p < .10$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Correlational analyses on inhibitory control effects

First, RTs and accuracies for the Flanker trial types were analyzed using a paired-sample *t* test. The RT analysis revealed a significant effect of trial type, $t(22) = -4.44$, $p < .001$, $d = -0.93$, showing faster performance in the congruent condition than in the incongruent condition. The accuracy analysis yielded a marginally significant effect of trial type, $t(22) = 1.73$, $p = .098$, $d = 0.36$. Descriptives for the Flanker task performance are presented in Table 6.

Subsequently, RTs of the word recognition task (cognates and noncognates) and of the Flanker task (congruent, incongruent, and Flanker effect) were entered into a correlational analysis (see Table 7). Given that semantic relatedness had no significant influence on the children's behavioral performance, the RTs of the semantically related and unrelated conditions were disregarded.

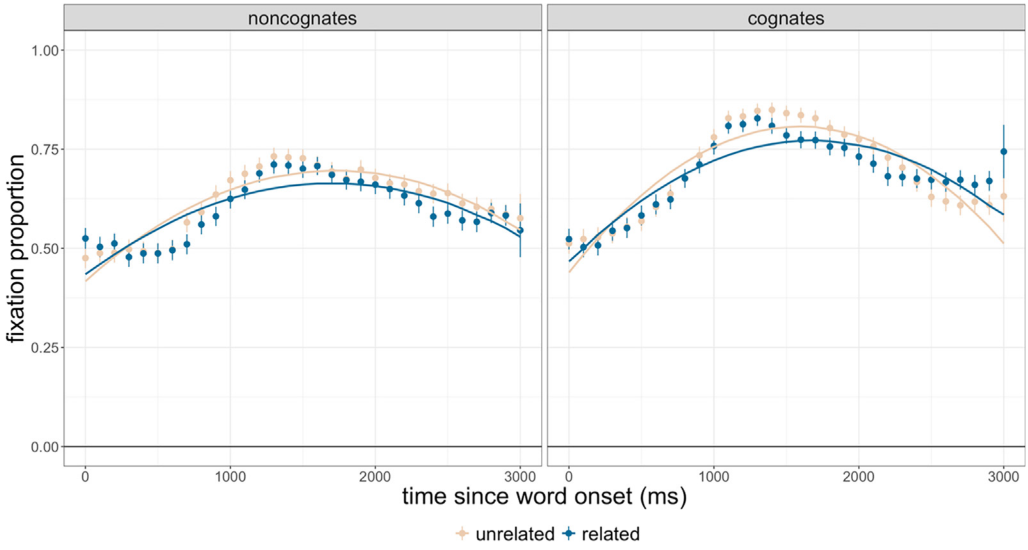

Fig. 4. Growth curve model for target fixations in post-naming phase for cognate status by semantic relatedness effects.

Table 6
Reaction times (in milliseconds) and accuracy rates by congruency in the Flanker task.

	Reaction time (ms)		Accuracy rate	
Congruent	1029	(267)	.94	(.04)
Incongruent	1094	(291)	.92	(.06)
Flanker effect	65		.02	

Note. Standard deviations are in parentheses.

Table 7
Pearson's *r* correlations (and *p* values) between RT performance on word recognition and Flanker task.

	1	2	3	4	5
1. Flanker congruent	–				
2. Flanker incongruent	.97*** (<.001)	–			
3. Flanker effect	.22 (.318)	.44* (.035)	–		
4. RT cognates	.43* (.040)	.46* (.027)	.27 (.215)	–	
5. RT noncognates	.53** (.009)	.60** (.003)	.44* (.035)	.78*** (<.001)	–

Note. RT, reaction time.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

The Flanker task yielded significant within-task correlations between congruent and incongruent conditions ($r = .97$, $p < .001$) and between incongruent condition and Flanker effect ($r = .44$, $p = .035$). Congruent condition and Flanker effect did not correlate ($r = .22$, $p = .32$).

The correlational analysis of RTs across tasks yielded significant correlations for cognates and the Flanker congruent condition ($r = .43$, $p = .04$) and incongruent condition ($r = .46$, $p = .027$), but none for cognate RTs and the Flanker effect ($r = .27$, $p = .22$). The noncognate RTs yielded a significant correlation with the congruent condition ($r = .53$, $p = .009$), the incongruent condition ($r = .60$, $p = .003$), and, critically, the Flanker effect ($r = .44$, $p = .035$). Building on correlational analyses reported in Poarch (2013), the results suggest that overall faster Flanker performance for the congruent and incongruent conditions has a positive effect on cognate and noncognate RT performance, although exerting a stronger impact on noncognate processing than on cognate processing. Moreover, the better the children were at inhibiting misleading information (indicated by a smaller difference score), the faster they were at responding to noncognates.

Discussion

The aim of this study was to gain further insight into lexical processing in child L2 learners by exploring whether young learners of English coactivate both languages during L2 word recognition. More specifically, it was investigated whether the children's performance was modulated by the target word's cognate status and by the semantic relatedness of the competitor picture to the target word. Furthermore, a correlational analysis between the participants' RTs for cognates and noncognates and their inhibitory control ability was performed to examine cognitive control effects on auditory word recognition performance.

Cognate facilitation effect

In line with previous findings (Bosma et al., 2019; Brenders et al., 2011; Von Holzen et al., 2019) and consistent with the current study's predictions, the participants exhibited a CFE in their nondominant L2. The children showed shorter response latencies, higher accuracy rates, and a steeper rise and fall in target fixation proportions for cognates than for noncognates. This highly significant effect of cognates found in both behavioral and eye-tracking data shows that L2 word recognition was affected by L1 lexical knowledge, supporting the language nonselective access hypothesis. The children used their German knowledge to process English cognate items; however, given no phonological overlap for noncognates, their German knowledge did not facilitate processing of the latter. Although lexical retrieval is generally slowed down by other phonologically similar words or neighborhood effects (see Mani & Plunkett, 2011), cognates did not impede but rather facilitated word recognition. Hence, cognate translation equivalents across languages did not compete but rather boosted lexical access due to their similarity. Through this cross-linguistic form overlap, cognate words' phonological nodes became activated in both languages, resulting in an activation of the semantic node via both the L1 and L2 routes. This is in line with the assumptions of the BIA+ model and shows that it is not a word's language membership that regulates the activation of corresponding orthographical, phonological, and semantic information but rather the similarity of the lexical input to the representations in the bilingual lexicon that does so (Dijkstra & Van Heuven, 2002).

Although the RHM (Kroll & Stewart, 1994) is a word production model, its fundamental findings regarding language coactivation can be mapped to the current study's word comprehension performance to a certain extent. The RHM proposes that in early L2 learners' word production, the access of meaning proceeds via the L1 translation equivalent until learners have become sufficiently proficient in their L2 to directly access the conceptual mediation route. Converging evidence comes from Von Holzen and Mani (2012), who examined cross-language priming effects in early L2-learning toddlers' word recognition. Hearing an L2 word was found to lead to activation of the L1 translation equivalent. Similarly, the current study's findings are consistent with the assumption that the retrieval of meaning was lexically mediated via the L1. Because the participants were L2 learners of English with low to intermediate proficiency, they were less likely to access meanings of the L2 words directly via conceptual links but rather accessed the words' meanings via the L1 translation equivalent. Consequently, during the word recognition task, the retrieval of cognate words in the children's nondominant L2 was facilitated by the phonologically similar L1 translation equivalent (Casaponsa et al., 2015). Thus, meaning could be accessed via L1 lexical links faster and more accurately for cognates than for noncognates, demonstrating a CFE in the children's L2. Furthermore, longer response latencies and lower accuracy rates for noncognates can be attributed to a reduced L2 experience because the noncognate L2 words might have been less salient to the children, resulting in a reduced capacity for word recognition. This processing disadvantage for noncognates compared to cognates was also manifested in noncognates being responded to not only less accurately but also less in general, with a higher omission rate for noncognates (11.8%) compared to cognates (3.1%).

Moreover, the 1500-ms preview of the target and competitor picture could have also contributed to a processing benefit for cognates by preactivating the L1 lexical representations of the displayed pictures before auditory stimulus onset. It can be assumed that this preactivation took place mainly via L1 lexical representations because the participants had lower L2 proficiency and thus were more likely to have stronger lexical representations in their dominant language (see Singh, 2014). With auditory stimulus onset, the children then needed to decide which of the two pictures matched the previously heard L2 item. During this decision-making process, the participants needed to evaluate both competing pictures and their concomitant preactivated L1 lexical representations. To handle this competition, the children needed to draw on their inhibitory control to suppress the misleading and nonrelevant information (see Prior et al., 2013, for inhibition in translation recognition and translation production). On the one hand, the children needed to inhibit the previously activated information from the competing L1 translation of the competitor item. On the other hand, the children also needed to suppress potentially misleading information within the target L1 lexical representations. Such inhibition of previously activated representations takes time and slows down processing (see Green's [1998] IC model for the bilingual lexicosemantic system). For cognate target words, L1 representations do not need to be inhibited—or only to a smaller degree (i.e., non-overlapping parts). Thus, the L1 facilitated the identification of the correct picture due to the phonological similarity to the L2 auditory input, which sped up decision making for cognates. For noncognates, however, the previously activated L1 representation impeded identification and required more inhibition due to the lack of form overlap, which slowed down processing. Thus, EF helped to inhibit the impeding L1 noncognate word form (see also lateral inhibition in Multilink; Dijkstra et al., 2019). This was also confirmed by the correlational analysis. It revealed a positive correlation between the Flanker effect and noncognate RT performance in the word recognition task, indicating that the better the children were at inhibiting misleading information in the Flanker task, the faster they were at responding to noncognate items. Thus, better inhibitory control facilitated the processing of the more demanding noncognate items (see Poarch, 2013; see also Mercier et al., 2014, for increased inhibitory control facilitating the inhibition of lexical competitors). Moreover, the overall faster Flanker performance in both congruent and incongruent conditions correlated significantly with an overall better RT performance in both the cognate and noncognate conditions, although exerting a stronger effect on noncognate processing. This can be regarded as evidence of cognitive control modulating the monitoring of such a word recognition task.

Concerning the current study's second hypothesis assuming that cognates with greater phonological overlap are processed faster than cognates with less phonological overlap, the findings of previous studies showing a gradual CFE in bilingual children's word recognition (Bosma et al., 2019; Von Holzen et al., 2019) could not be replicated. The advantage of cognate processing compared to noncognate processing indicates that the children were in fact sensitive to phonological similarity between L1 and L2; however, the degree of similarity did not modulate their cognate recognition, reasons for which can only be speculated about. One factor could be how phonological overlap is measured. Whereas the current study used the LD metric to do so, it can be recommended for future research to assess the phonological overlap of cross-linguistic word pairs by analyzing more precise phonological feature changes as well as the similarity of the translation equivalents' onsets (see, e.g., Kohnert et al., 2004; Von Holzen et al., 2019).

Semantic interference effect

With regard to context effects on L2 word recognition, the behavioral results revealed no effect of semantic relatedness, whereas the eye-tracking data analysis did. Particularly the GCA yielded a significant effect, with it being more likely that participants looked at target items presented with semantically unrelated competitors than at items with related competitors. In sum, an SIE for related items occurred but was only observable in the children's eye movements.

According to the predictions made by the RHM, early L2 learners are more likely to access semantic representations via L1 lexical links than via a direct conceptual route. Thus, beginning L2 learners should show less sensitivity to interference on a level of semantic relatedness but a greater effect of word form because L2 processing in early L2 learners is rather lexically mediated than conceptually mediated. Accordingly—and if these assumptions for word production are applied to word recognition—early L2 learners should rely more strongly on word form representations during word recognition than on semantic representations. This view can be supported by the current study's behavioral results, which only yielded an effect of word form and no semantic interference, thereby implying that the children did not access meaning directly via conceptual links but rather relied on the lexical route via the L1.

However, the eye-tracking results did yield a significant effect of semantic relatedness, revealing that the children were more likely to fixate the target picture when it was presented with an unrelated competitor. Consequently, a lower target fixation rate was scored when the target picture was presented with a related competitor picture, which distracted the children and impeded their decision making because the two displayed items shared connections within the semantic network (see also Chow et al., 2017). Although the semantic relatedness effect was only observable in the eye-tracking data and was comparatively weaker than the effect of word form, there is evidence for accessing meaning via the conceptual route even in these less proficient language users (see Poarch et al., 2015, for similar findings with beginning learners of L2 English).

Brysbaert and Duyck (2010) similarly concluded that the direct links between L2 words and their corresponding meanings are stronger than originally assumed by the RHM. In their review of the model, Kroll et al. (2010) likewise revised their initial assumption of a weak bidirectional link between L2 word and concept and argued for an asymmetric link. Thus, whereas the access from concepts to L2 words still requires more effort, the access from L2 words to concepts might proceed more easily. Considering the current study's finding that—contrary to the original assumptions of the RHM—the effect of semantic relatedness occurs even for low to intermediate proficient L2 learners, it bears repeating that the RHM aimed to depict word production, not word recognition. However, because learners' receptive L2 vocabulary knowledge is usually greater than their productive L2 lexical knowledge, semantic interference could have been stronger in this word recognition task than it might have been in a word production task. Because word recognition requires less effort to retrieve information compared to word production, accessing meaning from word to concept via the direct conceptual route might be accomplished more easily than vice versa (see also Kroll et al., 2010, suggesting an asymmetric link between L2 word and concept relative to task modality). Hence, L2 production task performance might have depended on participants' L2 proficiency to a larger extent (Prior et al., 2013; see also Kroll et al., 2002, for larger CFEs in word naming for low-proficient L2 learners compared to high-proficient L2 learners) and therefore yielded results that more resemble the original assumptions of the RHM.

Given these results, it can be concluded that even young learners with lower L2 English proficiency are influenced by semantic relatedness during word recognition. This conclusion is also supported by the significant three-way interaction among semantic relatedness, cognate status, and both linear and quadratic GCA time terms, confirming the initial prediction that cognate items presented with a semantically unrelated competitor item facilitate processing the most. Nevertheless, the CFE was stronger than the SIE, revealing stronger and more distinct lexical links to L1 word form than conceptual links in the L2 for these early L2 learners. A possible explanation could be the double activation on the word level due to a combination of access via the lexical and conceptual routes, whereas processing of semantic relatedness proceeded via conceptual activation (RHM; Kroll & Stewart, 1994).

Nonetheless, the preview of target and competitor picture might have also impacted the children's processing regarding the influence of semantic relatedness. With displaying the two pictures 1500 ms prior to auditory stimulus onset, the pictures preactivated not only the L1 lexical representations but also the respective concepts and their concomitant semantic networks. Thus, it could be argued that the preview might have weakened the semantic relatedness effect on L2 word recognition because the pictures and the subsequent L1 word activations could have been sufficient enough to cause an activation of the corresponding concepts prior to auditory L2 input. Because the L1 word-to-concept links had already been established, the preactivation on the level of word form might have facilitated L2 word recognition to such an extent that interference from semantic relatedness was pushed into the background. In addition, the computational model Multilink (Dijkstra et al., 2019), which combines the assumptions of the RHM and BIA+ model and aims to represent both bilingual word recognition and production, predicts that the phonological activation of words is faster than the activation of semantic nodes, which might also explain the enhanced preactivation on the word form level. The relatively weaker effect of semantic relatedness compared to that of word form is also evident from semantic relatedness only being significant in the eye movement data. Consequently, future research could conduct a similar experiment without a preview. Dropping the preview might modulate the processing of the auditory input, and thus a simultaneous presentation of auditory and visual stimuli could provide a clearer view on whether the children are more likely to access the concept via the L1 lexical link or via the direct conceptual route.

Conclusion

How exactly the mental representations that underlie bilingual language processing are structured and how information is retrieved during word recognition and production are questions that research on L2 processing is still trying to answer. Hence, this study offers new insights into how L2 words are connected to concepts and their L1 lexical counterparts in young L2 learners. In sum, the current study corroborated previous empirical research, revealing that both word form and semantic relatedness can affect word recognition in child L2 learners with low to intermediate levels of L2 proficiency. Thus, several conclusions regarding the processing of cognates and noncognates as well as meaning representations in young L2 learners have been made. First, cognate facilitation arose in L2 word recognition depicting a processing advantage of phonologically similar translation equivalents. However, the degree of phonological overlap did not modulate processing. Second, an SIE was observed in the children's eye movement data, showing that even child L2 learners can already access meanings of L2 words via direct activation of concepts. Nonetheless, word form effects were greater than semantic relatedness effects. Furthermore, the children's overall performance in the word recognition task was facilitated for noncognate processing by greater inhibitory control skills. Thus, the results suggest that cross-language activation during word recognition is affected to a large extent by phonological word form in these young L2 learners irrespective of the degree of phonological overlap the cognate word pairs share, that the processing of noncognates depends to a greater extent on inhibitory control than cognate processing, and that child L2 learners are able to not only exploit lexical links during word recognition but also direct conceptual links.

Regarding future research on cross-language activation during young L2 learners' word recognition, it would be of interest to explore whether the current study's findings can be corroborated with speakers of higher L2 proficiency given that the children's English proficiency in the current study had a marginally significant impact on their word recognition performance. In addition, bilingual L1 word recognition could be similarly investigated to assess whether even less proficient L2 learners show an effect of their low-proficient L2 on their dominant L1 and whether SIEs increase when tested in their dominant language. Furthermore, it might also be of interest to replicate the current study with English monolingual toddlers given that effects of cognate status are unlikely to be found in monolinguals (see Von Holzen et al., 2019), although the effect of semantic interference in L1 processing compared to this study's L2 processing context may give further comparative insight into conceptual representations in young L2 learners. In addition, the impact of EF on L2 word recognition could be further assessed with a greater focus on individual differences in L2 proficiency within a population of child L2 learners, which could provide further insight into developmental processes of bilingual language comprehension.

Acknowledgments

We thank Katie Von Holzen and Sarah Schimke for their helpful advice, Jodie Beckmann for the recordings, and all children, parents, and teachers who participated in this study. This research was conducted while both authors were at the University of Münster and did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2022.105443.

References

Anderson, J. A. E., Mak, L., Keyvani Chahi, A., & Bialystok, E. (2018). The Language and Social Background Questionnaire: Assessing degree of bilingualism in a diverse population. *Behavior Research Methods, 50*, 250–263.
Basnight-Brown, D. M., & Altarriba, J. (2007). Differences in semantic and translation priming across languages: The role of language direction and language dominance. *Memory & Cognition, 35*, 953–965.
Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01.
Bosma, E., Blom, E., Hoekstra, E., & Versloot, A. (2019). A longitudinal study on the gradual cognate facilitation effect in bilingual children's Frisian receptive vocabulary. *International Journal of Bilingual Education and Bilingualism, 22*, 371–385.
Bosma, E., & Pablos, L. (2020). Switching direction modulates the engagement of cognitive control in bilingual reading comprehension: An ERP study. *Journal of Neurolinguistics, 55* 100894.
Brenders, P., Van Hell, J. G., & Dijkstra, T. (2011). Word recognition in child second language learners: Evidence from cognates and false friends. *Journal of Experimental Child Psychology, 109*, 383–396.
Brysbaert, M., & Duyck, W. (2010). Is it time to leave behind the Revised Hierarchical Model of bilingual language processing after fifteen years of service? *Bilingualism: Language and Cognition, 13*, 359–371.
Brysbaert, M., & New, B. (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods, 41*, 977–990.
Casaponsa, A., Antón, E., Pérez, A., & Duñabeitia, J. A. (2015). Foreign language comprehension achievement: Insights from the cognate facilitation effect. *Frontiers in Psychology, 6*. https://doi.org/10.3389/fpsyg.2015.00588.
Chow, J., Aimola Davies, A., & Plunkett, K. (2017). Spoken-word recognition in 2-year-olds: The tug of war between phonological and semantic activation. *Journal of Memory and Language, 93*, 104–134.
Comesaña, M., Perea, M., Piñeiro, A., & Fraga, I. (2009). Vocabulary teaching strategies and conceptual representations of words in L2 in children: Evidence with novice learners. *Journal of Experimental Child Psychology, 104*, 22–33.
Costa, A., Santesteban, M., & Caño, A. (2005). On the facilitatory effects of cognate words in bilingual speech production. *Brain and Language, 94*, 94–103.
Dahan, D., & Tanenhaus, M. K. (2004). Continuous mapping from sound to meaning in spoken-language comprehension: Immediate effects of verb-based thematic constraints. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, 498–513.
Delle Luche, C., Durrant, S., Poltrock, S., & Floccia, C. (2015). A methodological investigation of the Intermodal Preferential Looking paradigm: Methods of analyses, picture selection and data rejection criteria. *Infant Behavior and Development, 40*, 151–172.
Dijkstra, T. (2005). Bilingual visual word recognition and lexical access. In J. F. Kroll & A. M. B. De Groot (Eds.), *Handbook of bilingualism: Psycholinguistic approaches* (pp. 179–201). New York: Oxford University Press.
Dijkstra, T., Miwa, K., Brummelhuis, B., Sappelli, M., & Baayen, H. (2010). How cross-language similarity and task demands affect cognate recognition. *Journal of Memory and Language, 62*, 284–301.
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*, 175–197.
Dijkstra, T., Wahl, A., Buytenhuijs, 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*, 657–679.
Dink, J., & Ferguson, B. (2018). *EyetrackingR* (R package Version 0.1.8) [computer software]. http://www.eyetracking-R.com.
Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*, 143–149.
European Federation of Academies of Sciences and Humanities (2017). *The European Code of Conduct for Research Integrity*. Berlin: Author.
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* 104086.
Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition, 1*, 67–81.
Huang, Y., & Snedeker, J. (2020). Evidence from the visual world paradigm raises questions about unaccusativity and growth curve analyses. *Cognition, 200* 104251.
Huettig, F., Rommers, J., & Meyer, A. S. (2011). Using the visual world paradigm to study language processing: A review and critical evaluation. *Acta Psychologica, 137*, 151–171.
Jäger, K., Schmidt, M., Conzelmann, A., & Roebers, C. M. (2014). Cognitive and physiological effects of an acute physical activity intervention in elementary school children. *Frontiers in Psychology, 5*. https://doi.org/10.3389/fpsyg.2014.01473.
Kleiner, S., & Knöbl, R. (Eds.). (2015). *Duden, das Aussprachewörterbuch* (7th rev. ed.). Mannheim, Germany: Dudenverlag.
Kohnert, K., Windsor, J., & Miller, R. (2004). Crossing borders: Recognition of Spanish words by English-speaking children with and without language impairment. *Applied Psycholinguistics, 25*, 543–564.
Kroll, J. F., Bobb, S. C., & Hoshino, N. (2014). Two languages in mind: Bilingualism as a tool to investigate language, cognition, and the brain. *Current Directions in Psychological Science, 23*, 159–163.
Kroll, J. F., Michael, E., Tokowicz, N., & Dufour, R. (2002). The development of lexical fluency in a second language. *Second Language Research, 18*, 137–171.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language, 33*, 149–174.
Kroll, J. F., Van Hell, J. G., Tokowicz, N., & Green, D. W. (2010). The Revised Hierarchical Model: A critical review and assessment. *Bilingualism: Language and Cognition, 13*, 373–381.
Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 English words. *Behavior Research Methods, 44*, 978–990.
Law, F., & Edwards, J. R. (2015). Effects of vocabulary size on online lexical processing by preschoolers. *Language Learning and Development, 11*, 331–355.
Levenshtein, V. I. (1966). Binary codes capable of correcting deletions, insertions, and reversals. *Soviet Physics Doklady, 10*, 707–710.
Mani, N., & Plunkett, K. (2011). Phonological priming and cohort effects in toddlers. *Cognition, 121*, 196–206.
Maris, E., & Oostenveld, R. (2007). Nonparametric statistical testing of EEG- and MEG-data. *Journal of Neuroscience Methods, 164*, 177–190.
Méndez Pérez, A., Peña, E. D., & Bedore, L. M. (2010). Cognates facilitate word recognition in young Spanish-English bilinguals' test performance. *Early Childhood Services, 4*, 55–67.
Mercier, J., Pivneva, I., & Titone, D. (2014). Individual differences in inhibitory control relate to bilingual spoken word processing. *Bilingualism: Language and Cognition, 17*, 89–117.
Mirman, D., Dixon, J. A., & Magnuson, J. S. (2008). Statistical and computational models of the visual world paradigm: Growth curves and individual differences. *Journal of Memory and Language, 59*, 475–494.
Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21*, 8–14.
Pivneva, I., Mercier, J., & Titone, D. (2014). Executive control modulates cross-language lexical activation during L2 reading: Evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*, 787–796.
Poarch, G. J. (2013). *Cross-language interaction, word representation, and cognitive control in second language learners, bilinguals, and trilinguals*. Radboud University. Unpublished doctoral dissertation.
Poarch, G. J. (2018). Multilingual language control and executive function: A replication study. *Frontiers in Communication, 3*. https://doi.org/10.3389/fcomm.2018.00046.
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*, 419–438.
Poarch, G. J., & Van Hell, J. G. (2014). Cross-language activation in same-script and different-script trilinguals. *International Journal of Bilingualism, 18*, 693–716.
Poarch, G. J., & Van Hell, J. G. (2019). Does performance on executive function tasks correlate? Evidence from child trilinguals, bilinguals, and second language learners. In I. A. Sekerina, L. Spradlin, & V. Valian (Eds.). *Studies in bilingualism* (Vol. 57, pp. 223–236). Amsterdam: John Benjamins.
Poarch, G. J., Van Hell, J. G., & Kroll, J. F. (2015). Accessing word meaning in beginning second language learners: Lexical or conceptual mediation? *Bilingualism: Language and Cognition, 18*, 357–371.
Prior, A., Kroll, J. F., & MacWhinney, B. (2013). Translation ambiguity but not word class predicts translation performance. *Bilingualism: Language and Cognition, 16*, 458–474.
R Core Team (2019). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.
Ronjat, J. (1913). *Le développement du langage observé chez un enfant bilingue*. Paris: H. Champion.
Schelletter, C. (2002). The effect of form similarity on bilingual children's lexical development. *Bilingualism: Language and Cognition, 5*, 93–107.
Schepens, J., Dijkstra, T., Grootjen, F., & Van Heuven, W. J. B. (2013). Cross-language distributions of high frequency and phonetically similar cognates. *PLoS One, 8*(5) e63006.
Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime reference guide*. Pittsburgh, PA: Psychology Software Tools.
Singh, L. (2014). One world, two languages: Cross-language semantic priming in bilingual toddlers. *Child Development, 85*, 755–766.
Szekely, A., Jacobsen, T., D'Amico, S., Devescovi, A., Andonova, E., Herron, D., Lu, C. C., Pechmann, T., Pléh, C., Wicha, N., Federmeier, K., Gerdjikova, I., Gutierrez, G., Hung, D., Hsu, J., Iyer, G., Kohnert, K., Mehotcheva, T., ... Bates, E. (2004). A new on-line resource for psycholinguistic studies. *Journal of Memory and Language, 51*, 247–250.
University of Münster. (2002). Rules of good scientific practice of the University of Münster. www.uni-muenster.de/imperia/md/content/wwu/senat/pdf/kodex_en_22_11_2017.pdf.
Vales, C., & Fisher, A. V. (2019). When stronger knowledge slows you down: Semantic relatedness predicts children's co-activation of related items in a visual search paradigm. *Cognitive Science, 43* e12746.
Van Hell, J. G., & Dijkstra, T. (2002). Foreign language knowledge can influence native language performance in exclusively native contexts. *Psychonomic Bulletin & Review, 9*, 780–789.
Van Heuven, W. J. B., Mandera, P., Keuleers, E., & Brysbaert, M. (2014). SUBTLEX-UK: A new and improved word frequency database for British English. *Quarterly Journal of Experimental Psychology, 67*, 1176–1190.
Von Holzen, K., Fennell, C. T., & Mani, N. (2019). The impact of cross-language phonological overlap on bilingual and monolingual toddlers' word recognition. *Bilingualism: Language and Cognition, 22*, 476–499.
Von Holzen, K., & Mani, N. (2012). Language nonselective lexical access in bilingual toddlers. *Journal of Experimental Child Psychology, 113*, 569–586.