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ARTICLE

Bilingual Toddlers' Vocabulary Growth Interacts with Existing Knowledge and Cross-Linguistic Similarity

Serene Siow[1,2], Irina Lepadatu[1], Nicola A. Gillen[1] and Kim Plunkett[1]

[1]Department of Experimental Psychology, University of Oxford, Oxford, UK and [2]Department of English, Linguistics & Theatre Studies, National University of Singapore, Singapore, Singapore
Corresponding author: Serene Siow; Email: s.siow@nus.edu.sg

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Abstract
We explored whether bilingual toddlers make use of semantic and phonological overlap between their languages to learn new words. We analysed cross-sectional and longitudinal CDI data on the words understood and produced by 1.0 to 3.0-year-old bilingual toddlers with English and one additional language. Cognates were more likely to be understood and produced compared to non-cognates. Cognate effects were modulated by whether the toddler knew the translation equivalent in the other language, highlighting that young learners are sensitive to the similarities across their languages. Additionally, exploratory analyses suggest that children with smaller vocabularies rely more on translation equivalents to support the acquisition of difficult words. Children with larger vocabulary sizes exhibited no preference for translation equivalents in comprehension, and a preference for new concepts in production. The rapid acceleration of vocabulary growth in the second year of life may explain this developmental change in translation equivalent preference.

Keywords: bilingualism; cognate; longitudinal; translation equivalents; vocabulary growth

1. Background

Many studies have identified a vocabulary size lag in bilingual children relative to monolinguals, particularly when vocabulary size is calculated using a single language (e.g., Bialystok et al., 2010; Cattani et al., 2014; Hoff et al., 2012; Pearson et al., 1993; Pearson et al., 1997). However, other studies indicate that exposure to both languages at home is not detrimental to the acquisition of a minority language, and in fact, supports acquisition of the majority language (Umbel et al., 1992; Umbel & Oller, 1994). In a study with learners of English, while bilingual first graders' performance for English (the majority language) was lower than the mean of the norming sample, the sixth graders performed near the mean (Umbel & Oller, 1994). Such results suggest that despite an early vocabulary gap in the majority language for bilinguals, this gap decreases with age and exposure.

Nonetheless, the identification of vocabulary lag at the younger ages has led to research looking into strategies for helping bilingual children overcome this gap earlier. A unique feature of the bilingual learning environment is that the two languages are interlinked by words which share meaning. These dual-language word pairs are known as translation equivalents. Learners of two languages may make use of such overlap to support their learning. The term doublet has been used by various studies in the bilingual literature (De Houwer et al., 2006; Pearson et al., 1995; Pearson & Fernández, 1994) to refer to translation equivalents that a child has learned in both languages. To give an example, if an English-Spanish bilingual child knows the English word "dog" as well as its Spanish translation equivalent "perro", the child is said to know a doublet. This contrasts with cases where only one word of the pair is known, referred to as singlets. By the second year of life, bilingual children typically understand words in both of their languages, including many doublets (De Houwer et al., 2006; Legacy et al., 2017; Pearson et al., 1995; Siow et al., 2023). Poulin-Dubois et al. (2013) found that 2-year-old bilinguals who knew more doublets were faster to recognise words in a receptive vocabulary task, even after accounting for effects of vocabulary size.

Given that doublets are present in bilingual children's early vocabularies, one question is whether translation equivalents hold privileged status in word learning. Translation equivalents may be easier to learn than new concepts. This account, generally referred to as the preference account, has been supported by some studies like Bilson et al. (2015) and Tsui et al. (2022) for toddlers with smaller vocabulary sizes below 300 words. Interestingly, Tsui et al. (2022) found that the word acquisition trajectory of bilingual toddlers with larger vocabularies (exceeding 300 words) fits better with a neutral account. The neutral account posits that translation equivalents are not easier to learn than new concepts, nor are they more difficult. Patterns supporting the neutral account have also been found by Pearson et al. (1993). Such an account can explain the mix of both singlets and doublets in bilingual children's vocabularies. Accounts of bilingual word acquisition must consider that there may be incidental learning of translation equivalents (Łuniewska et al., 2016), as word acquisition orders in each language are likely to be guided by common factors. Words that are more frequent in child-directed speech are learned earlier (Braginsky et al., 2019; Hills et al., 2010; Storkel, 2004), as are shorter words (Storkel, 2004) and words that occur in diverse speech contexts (Hills, 2013). Concrete nouns for labelling objects are learned earlier than other word types such as verbs and adjectives (Bergelson & Swingley, 2015; Li & Fang, 2011). These common factors affecting word acquisition order are likely to contribute to the acquisition of incidental doublets.

1.1. Cognate facilitation effect

Translation equivalent pairs with shared phonology, orthography, and etymology, for example English *train* and Spanish *tren*, are known as cognates. The parasitic model of second language learning (Hall, 2002) proposes that learners of a second language are sensitive to form similarities between languages and can make use of such similarities to learn words in their second language more easily. The cognate facilitation effect has been used as support for the idea that lexical representations from both languages are simultaneously activated in word recognition and production (Costa et al., 2000).

Past research has found advantages of similarity between languages on vocabulary development in young bilinguals. The "picture naming" advantage for cognates found by Costa et al. (2000) was replicated by Poarch and Van Hell (2012) in both adults and school-

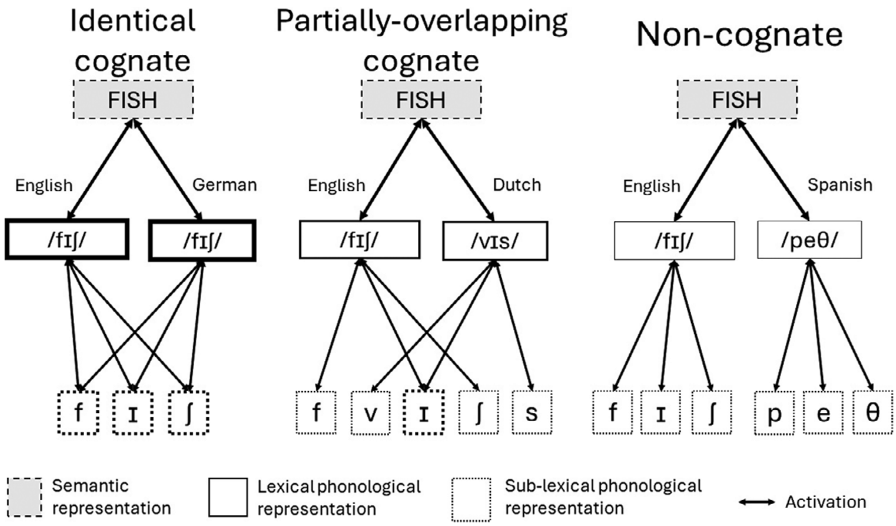

Figure 1. Diagram of the cascaded activation model, with examples of an identical cognate, a partially overlapping cognate with 1 phoneme match, and a non-cognate with zero matches.

aged (5–8 years old) children. Advantages have been found for cognates over non-cognates for children's performance on receptive vocabulary tasks (Bosma et al., 2019; Pérez et al., 2010), word production tasks (Bosch & Ramon-Casas, 2014; Koutamanis et al., 2024b), lexical decision (Koutamanis et al., 2024a), and vocabulary knowledge as measured using parent-report inventories (Mitchell et al., 2023). This cognate advantage has also been found for the acquisition of a second language by adult learners (Otwinowska & Szewczyk, 2017) and school-aged children (Tonzar et al., 2009). Young bilingual children whose languages are more similar may have larger total vocabulary sizes (Blom et al., 2020; Floccia et al., 2018; Gampe et al., 2021).

The cognate facilitation effect is posited to operate via cascaded activation between lexical nodes and their phonological segments (Costa et al., 2000). Under a non-selective bilingual lexical access account, when a word is activated, it also activates its translation equivalent. The lexical nodes feed activation to their corresponding phonological nodes, and the phonemes that overlap across the two words feed activation back to the lexical nodes, heightening the activation of cognate words. The more the phonemes overlap, the stronger the activation of the lexical nodes, and subsequently, there is better recognition for cognates with higher similarity (Bosma et al., 2019; Saiegh-Haddad & Haj, 2018; Von Holzen et al., 2019). In these studies, identical cognates exhibited the strongest effect, and there was an advantage for partially overlapping cognates over non-cognates. Figure 1 shows examples of English *fish* /fɪʃ/ with an identical cognate German *Fisch* /fɪʃ/, partially overlapping cognate Dutch *vis* /vɪs/, and non-cognate Spanish *pez* /peθ/.

1.2. Language proficiency and cognate facilitation

An extensive literature on cognate facilitation has shown that cognate facilitation is more prominent when adults are tested in their less proficient language, with evidence across a variety of tasks (Allen, 2019; Bultena et al., 2014; Costa et al., 2000; Kroll et al., 2002; Poarch & Van Hell, 2012; Van Hell & Dijkstra, 2002).

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Variable strength of the cognate facilitation effect has also been found in children. Larger cognate facilitation was found in children who were less dominant in the test language than children who were dominant in that language, both with three to five-year-olds (Robinson et al., 2020) and five- to seven-year-olds (Pérez et al., 2010). When Dutch-English bilingual children were tested on lexical decision tasks in both their first and second languages, all children aged ten-, twelve-, and fourteen showed faster recognition for cognates than non-cognates in their L2 (Dutch) but not in their L1 (English) (Brenders et al., 2011). Likewise, Poarch and Van Hell (2012) only found facilitation in the L2 (English) for picture naming test performance of German-English bilingual children (five- to eight-year-olds) but not when children were tested in their L1 (German). For less proficient language learners, lexical access to L2 words may be mediated by the translation in their L1 (Kroll & Stewart, 1994). L2 learners may draw upon similarities between the L2 word and the more familiar L1 word to help process words in L2 (Kroll et al., 2002).

There is evidence that learners become less dependent on cross-linguistic similarity as their second language proficiency grows. In a study with eight to fifteen-year-old children, reliance on cognates for reading comprehension in the L2 was stronger in younger children (who were less proficient in reading) than older children (who had grown more familiar with the printed word) (Duñabeitia et al., 2016). However, seemingly in direct contrast to the findings on the relationship between proficiency and the size of the cognate facilitation effect, in Bosma et al.'s (2019) study, the observed cognate facilitation effect increased with age, suggesting that children became more aware of form similarity between languages as they gained more language experience. Van Hell and Tanner (2012) suggested that cognate facilitation effects in the test language may only manifest if learners have achieved a minimum level of proficiency in the non-test language. This claim is supported by the findings in Poarch and Van Hell (2012) that balanced child bilinguals (exposed to both languages at home, average 2.67 years immersion) showed cognate facilitation in both English and German.

If the cognate facilitation effect is dependent on a strong existing lexical representation, can toddlers who are still in the early stages of learning make use of cognates in their word learning? There is evidence that even toddlers are sensitive to cross-linguistic similarity across their languages. Even 1.6- to 4.5-year-old English-German bilingual toddlers showed the asymmetry of the cognate facilitation effect found in older children and adults, with strong phonological overlap facilitating word recognition in bilinguals' L2 (English) but no significant effect on word recognition in L1 (German) (Von Holzen et al., 2019). Studies of vocabulary size trajectories in bilingual toddlers have also provided support for an effect of cross-linguistic similarity on young bilinguals' word learning. Gampe et al. (2021) studied toddlers (1.6–2.6 years) learning Swiss German and one other language, finding larger vocabularies in toddlers whose other language was closer to Swiss German. Floccia et al. (2018) measured the vocabularies of two-year-old UK bilingual toddlers using vocabulary inventories, with a large sample of bilingual toddlers growing up with English and one of thirteen additional languages. For vocabulary in production, they found that learners of additional languages with higher average phonological similarity to English showed larger vocabulary sizes in the additional language. For vocabulary in comprehension, learners of additional languages with similar word order typology or similar levels of morphological complexity with English had larger vocabulary sizes. Findings from Koutamanis et al. (2024b) suggest that advantages of more similar languages can be partially but not fully explained by effects of phonological similarity between words. Children learning more similar languages had better performance on word production even after excluding cognates with high similarity. However, tested non-cognates may be similar in

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other ways despite low phonological similarity, for example, in phonetic features or morphological features. An unexpected finding in Koutamanis et al.'s study was that children learning more distant languages were more strongly affected by effects of word-level phonological similarity. They theorised that the relatively few cognates present in distant languages may make cognates more salient to the learner, thereby heightening the cognate facilitation effect. Taken together, these studies highlight that the effects of cross-linguistic similarity on learning are complex and merit further investigation.

1.3. The present study

Our aim was to study whether the vocabulary advantage observed for learners of more similar languages in Floccia et al. (2018) can be observed at the word level, where we expect that more similar words will be learned earlier. Evidence for cognate facilitation in toddlers' vocabulary trajectories would lend support to theories of simultaneous bilingual lexical activation, specifically that the mechanism is applicable even at this early stage of language development. We explored the hypothesis that cognate facilitation only occurs when the learner has an existing lexical representation of one word in a cognate pair. Under the simultaneous lexical access hypothesis, hearing English *train* triggers the automatic activation of the Spanish word *tren* (if the Spanish word is present in the learner's vocabulary) via the overlapping phonemes shared between these words. The activation supports the strengthening of the newly learned word form. If the word *tren* is not in the learner's vocabulary, there should be no difference between the English-Spanish cognate "train" and the non-cognate "truck". On the other hand, if simultaneous lexical activation is not applicable to toddlers, we expect to see no facilitation, as the Spanish translation equivalent *tren* would be inactive and therefore unable to exert cross-linguistic facilitation.

Following from previous research, we also investigated effects of language dominance on cognate facilitation. We were interested to test whether findings of stronger facilitation effects in the less dominant language can be attributed to whether the translation is present in the learner's lexicon, given that learners are expected to know more words in their dominant language. Finally, we investigated whether translation equivalents offer facilitation even in the absence of obvious phonological overlap. Findings of facilitation in non-cognate translation equivalents would suggest that conceptual overlap between languages also supports word learning.

To study these research questions, we collected data online from bilingual families with children between one and three years old. As in Floccia et al. (2018), these families spoke a common language English and one additional language. As we were interested in word-level effects rather than language-level effects, we chose to focus on a smaller subset of seven languages from the thirteen in Floccia et al.'s study. Our tested additional languages covered three language families – Germanic, Romance and Slavic – which varied in the degree of common etymology and language contact they had with English.

Parents filled in two vocabulary inventories, one in English and one in the additional language. By collecting data in both languages for each bilingual child, we studied the interdependence between vocabulary acquisition trajectories in the two languages. A main advantage of the present study over Floccia et al. (2018) was the use of the 416-word Oxford CDI as opposed to the 100-word short-form Oxford CDI, along with additional language adaptations of the Oxford CDI formulated to have high conceptual overlap. The much larger number of concepts that overlapped across all the inventories (30 words for Floccia et al. (2018); more than 300 in the present study) allowed us to make more robust

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claims regarding word-level effects. Word pairs varied in phonological similarity both within a language and between languages, allowing us to employ a mixed design. Translation equivalent pairs may in some cases even present a naturally occurring crossed design. For example, the English word *fish* is a cognate with German *Fisch* but not Spanish *pez*, while the English word *animal* is a cognate with Spanish *animal* but not German *Tier*. By comparing the developmental trajectory of these English words between English-Spanish bilingual toddlers and English-German bilingual toddlers, we can tease apart the effect of phonological similarity on word acquisition order when other word factors are held constant.

Another key strength of this study was the collection of longitudinal vocabulary data. A limitation of cross-sectional data is that we can only make claims about vocabulary knowledge at a given point of time, and not whether two words are learned in quick succession or with a large time gap. With our longitudinal data collected at two-month intervals, we can make stronger claims about how phonological similarity and translation equivalents may jointly or independently affect which words are learned earlier.

2. Study 1: Cross-sectional data

The aim of Study 1 was to investigate whether cognates facilitate vocabulary learning in this population of bilingual toddlers, and whether toddlers' language dominance and existing lexicon affects the strength of the cognate facilitation effect. The research questions were:

1. Are words that are cognates more likely to be known than non-cognates?
2. Is the cognate facilitation effect stronger in the less-dominant language?
3. Is the cognate facilitation effect dependent on comparison to the translation equivalent (TE), or are cognates simply easier to learn (e.g., due to systematic differences between cognate and non-cognate words)?

2.1. Methods

Participants. This study was conducted in accordance with the ethical standards of the British Psychological Society. It received ethical approval from the Medical Sciences Research Ethics Board at the University of Oxford, reference number R60939/RE009. Informed consent was obtained from the caregiver who filled in the surveys. Recruitment was conducted via advertisements on social media and emails to families in the laboratory's database. The full sample consisted of 1;0 to 3;0-year-old bilingual toddlers (N = 625; N female = 320, N male = 304, N other = 1) (age 1;0–3;0, mean 2;0 years) growing up with English and one other language (Dutch, French, German, Italian, Polish, Portuguese, or Spanish). Data were collected online from families living in the United Kingdom, Germany, the Netherlands, or Spain. As all the bilingual child participants had the common language of English, we will henceforth follow the convention used by Floccia et al. (2018) and refer to the non-English language as the additional language (AL). Families were sent an £5 e-gift voucher, a child-size t-shirt (UK participants) or a €5 e-gift voucher (other participants). Some families contributed longitudinal data—these data are analysed in Study 2. We excluded child participants reported to be premature (gestation weeks of less than 37 weeks and/or low birth weight of less than 2.5 kg), and those with hearing problems or diagnosed language delay. We selected the cut-off for prematurity based on studies where premature infants showed smaller vocabularies in the early years than their full-term peers (Zimmerman, 2018).

Demographics and language exposure questionnaires. We collected demographics information about each child's age, gender and parents' education level. Overall, socio-economic status as judged by parents' educational level was high, with 89.0% of mothers reported to hold a university degree or equivalent. To obtain estimates of the language environment, we used a language exposure questionnaire adapted from Bosch and Sebastián-Gallés (2001). The responding caregiver gave estimates on the percentage of overall exposure and exposure in the home for the languages their child was exposed to. They also reported the native language of each parent, which language(s) each parent usually used with the child, nursery attendance and the language(s) used at nursery, and the amount of time (if any) the child has spent immersed in a community where their home language is spoken widely.

Bilingual child participants in the sample were exposed at least 20% of the time to English and at least 20% to their AL. Children who heard 10% or more of a third language were excluded. All children in the UK sample had at least one parent who was a native speaker of the AL, while all children in the Germany/Netherlands/Spain samples had at least one parent who was a native speaker of English. Therefore, all sampled children were exposed to native input of the non-community language in the home. Distribution of the sample, split by toddlers' AL and country of residence is shown in Table 1.

Vocabulary inventories. We collected parent-report vocabulary inventories in English and the AL for each child. Parents marked whether their child understands and says, understands but does not say, or does not understand each word in the list. For English, we used the Oxford Communicative Development Inventory (CDI) (Hamilton et al., 2000). The Oxford CDI has been widely used in research with British toddlers, including Floccia et al. (2018) with bilingual toddlers. The Oxford CDI was normed using data from 669 British toddlers (1;0 to 2;1-years-old). It includes 418 words from 19 semantic categories.

Table 1. Number of participants per language, with mean age at time of response and mean percentage of overall English exposure

Language	Country	N	Mean age (months)	Mean Eng Exp (%)
Dutch	The Netherlands	24	25.0 (6.5)	52.9 (15.2)
Dutch	The United Kingdom	28	25.6 (6.7)	63.4 (15.9)
French	The United Kingdom	78	23.5 (7.3)	60.8 (16.4)
German	Germany	42	25.1 (7.2)	44.8 (17.6)
German	The United Kingdom	41	25.6 (6.2)	60.1 (16.2)
Italian	The United Kingdom	84	23.3 (6.5)	54.3 (16.2)
Polish	The United Kingdom	84	23.5 (7.4)	51.0 (18.9)
Portuguese	The United Kingdom	41	24.1 (6.4)	50.0 (18.6)
Spanish	Spain	70	25.2 (6.7)	50.7 (17.5)
Spanish	The United Kingdom	133	24.3 (7.2)	52.4 (17.2)
Total		625	24.3 (6.9)	53.7 (17.7)

Note: SD are in brackets

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For each AL, we created adaptations of the Oxford CDI by consulting native speakers of each language (one to three consultants per language). All consulted native speakers were also fluent in English. We started by translating the words in the Oxford CDI to each AL. The goal of these AL adaptations was not to establish independent inventories for these languages (there are existing inventories for most of these languages), but instead to obtain a set of bilingual inventories with as much overlap as possible. Henceforth, the term concept will be used to refer the common concept shared by a given set of translation equivalents (i.e., English “fish”, Dutch “vis” and Spanish “pez” share the concept FISH).

Where possible, we used the lexical entries from the MCDI adaptations in the respective languages. The remaining words were translated by the native speaker consultants. If there were multiple common words for the same concept (e.g. synonyms or words in different dialects), the words were listed in the same lexical entry (e.g., Spanish “contento/feliz” for English “happy”. This approach is based off the approach taken for the original English version of the Oxford CDI, like for the entry “pushchair/buggy”. For a small number of words, an item in the Oxford CDI was deemed by our consultants as not culturally relevant or not directly translatable to the AL. These words were substituted with appropriate replacements to maintain the length of the CDIs (416 words in each inventory).

Defining phonological similarity. To define phonological similarity between words, we calculated a similarity score derived from Levenshtein distance (Levenshtein, 1966). Levenshtein distance is the minimal edit distance required to change one string to another, where additions, subtractions, and substitutions contribute to the score. The higher the Levenshtein distance, the more dissimilar a pair of words. For example, to convert string /æpl/ (English “apple”) to /apfəl/ (German “Apfel”), we need 1 substitution of “æ” to “a” and 2 additions of “f” and “ə,” resulting in a Levenshtein distance of 3. While Levenshtein distance was originally formulated for calculating orthographic similarity, it has been used by various studies for calculating phonological similarity, including Floccia et al. (2018). This usage of Levenshtein distance treats all non-identical phonemes to be changes and applies an equal weight of 1 to each change. As such, there are limitations in how the measure handles non-identical but close phonemes. One justification for using this relatively coarse measure is that identical phonemes are expected to contribute the most weight to judgements of word similarity.

We applied several coding choices aimed to facilitate identification of word similarity using this coarse measure. As the studied languages had some language-specific phonetic features that could make cross-linguistic comparison difficult, we decided to ignore such phonetic features in the transcriptions. Namely, these phonetic features were consonant aspiration (present in English), vowel length (present in English, German, Dutch), vowel nasalisation (present in French, Portuguese, Polish), palatalisation (present in Polish), and labialisation (present in Polish). This choice mirrored the approach used by Tribushinina et al. (2023) when comparing English and Russian words. We were not able to account for dialectal differences within a language. All IPA transcriptions corresponded to the standard European variety of the language.

Levenshtein distance was used to count the number of phonemes different between IPA transcriptions of each word pair. The Levenshtein distance score was divided by the number of phonemes in the longer word in the TE pair, to obtain a standardised score that controlled for word length. Finally, a similarity score was obtained by calculating 1 – standardised Levenshtein distance, producing a score between 0 (maximally dissimilar) and 1 (identical). Returning to the previous example of /æpl/ and /apfəl/, the Levenshtein distance score of 3 is divided by 5 (number of phonemes in /apfəl/), and then converted to the similarity score of 0.4. We excluded identical cognates (operationalised as having similarity score of 1) from analyses. Onomatopoeia like meow (cat sound) and vroom (car sound) were also excluded, as the iconicity of these words, which mirror the physical sounds, may potentially overinflate the effect of cognates. Additionally, compound words like "rocking chair" were excluded as it was difficult to acquire frequency estimates for these words.

After exclusions, there were 301 concepts with translation equivalents across all eight tested languages. Full lists of analysed word pairs with their IPA transcriptions can be found on the Open Science Framework (OSF; link in Supplementary Materials).

We additionally derived a measure of overall language similarity to be used in exploratory analyses. The seven different ALs spoken by the sample can be separated into three language families (Germanic, Romance and Slavic). As these languages differed in the degree of similarity they have with English, we could test whether the overall language similarity affected vocabulary outcomes. Following Floccia et al. (2018), we defined overall language similarity for a given language pair as the average similarity score of the 301 analysed word pairs from that language pair. In order of increasing similarity with English, the languages were Polish (0.0963), Portuguese (0.105), Spanish (0.112), French (0.118), Italian (0.131), German (0.209), and Dutch (0.250).

Defining word difficulty. We used monolingual age-of-acquisition (AoA) norms as a proxy for word difficulty in the absence of bilingual effects. Words that were learned later by toddlers (i.e. have later AoA) were defined as being more difficult. AoA as derived from children's vocabulary data is correlated with imageability, object familiarity and word length (Morrison et al., 1997). We used AoA norms obtained from 1720 British English monolingual infants between 1;0- and 2;8-years of age, collected using the Oxford CDI (Hamilton et al., 2000). This sample combines unpublished data collected as part of online/lab studies between 2013 and 2020 ($N = 510$) and publicly available data collected by the Plymouth Babylab ($N = 1210$; Floccia, 2017). The latter data set was obtained from Wordbank (Frank et al., 2017), an open-source database of vocabulary data collected using CDIs. AoA in comprehension for a word was defined as the earliest age (in months) that the word was understood by at least 50% of toddlers of that age. AoA in production was defined as the earliest age that the word was produced by at least 50% of toddlers of that age. This method of applying a minimum threshold is common when defining AoA using child vocabulary knowledge data, for example in Morrison et al. (1997). When calculating AoA, we rounded toddlers' ages to the nearest month. A word difficulty score was then obtained by centering AoA scores by its mean (independently for comprehension and production) and scaling by standard deviation. We excluded English words with AoA that was more than 3SD from the mean in either direction. These cutoffs resulted in 4 words excluded for comprehension (297 words analysed) and 6 words excluded for production (295 words analysed).

Defining frequency. Frequency in the speech input has been widely associated with word acquisition trajectories. We derived frequency in child-ambient speech from British English CHILDES corpora (MacWhinney, 2000). Frequencies were represented as Zipf values using the formula of log10(frequency per million words) + 3. Zipf values have been found to be better correlated to acquisition norms than raw values. Frequency had a -.246 correlation (Pearson's r) with AoA.

Analysis plan. As English was the common language for all toddlers, we chose to investigate the effect of cognates on English vocabulary trajectories. To test the hypothesis that cognates will be learned earlier than non-cognates, we ran two binomial generalised linear mixed effects models with the following binary categorical dependent variables derived from the vocabulary inventories – English comprehension (understands or does not understand in English) and English production (produces or does not produce in English).

We included six main predictors in each model – phonological similarity, word difficulty, lexical frequency, toddler's age in months, toddler's percentage of overall English exposure, and whether or not the toddler knew the translation equivalent in their AL (*AL TE knowledge*). Phonological similarity, word difficulty, frequency, and age were continuous variables centred on the mean and scaled by standard deviation. English exposure was centred on 50% and scaled by standard deviation. The predictor AL TE knowledge had the reference level *does not understand/produce in AL.*

We also included two interactions in each model. To test the hypothesis that the cognate advantage only manifests when there is existing knowledge of the translation equivalent, we examined for an interaction between phonological similarity and AL TE knowledge. To study if the cognate advantage is stronger in the less dominant language, we examined for an interaction between phonological similarity and toddler's English exposure. If cognate facilitation benefits the weaker language more than the stronger language, we expect to see a negative interaction between these variables for English vocabulary (i.e., toddlers with less English exposure show a stronger effect of phonological similarity in English). Participants and concepts were included as random effects. The reference level of the dependent variable was *does not understand/produce in English.* The model syntax for the full model is shown below:

$$\begin{aligned}&\text{glmer}\,(\sim \text{age} + \text{English\_exposure} + \text{word\_difficulty} + \text{frequency} +\\&\text{AL\_TE\_knowledge} + \text{phon\_similarity} + \text{AL\_TE\_knowledge} : \text{phon\_similarity} +\\&\text{English\_exposure} : \text{phon\_similarity} + (1|\text{participant}) + (1|\text{concept})\,)\end{aligned}$$

To identify the unique variance contributed by the two interactions, the interactions were removed one at a time and compared against the full model. We used marginal R^2 and the Akaike Information Criterion (AIC) to evaluate the models. Marginal R^2 (R^2m) was obtained using the MuMiN package in R, which uses the delta method for deriving observation-level variance of a model relative to a null model with only the intercept term. The AIC, Chi-square statistics and p-values for comparing models were obtained using the ANOVA function in base R (R Core Team, 2013) and R Studio (Posit team, 2023). P values were obtained using lmerTest (Kuznetsova et al., 2017) via Satterthwaites approximation degrees of freedom. To report effect sizes, we calculated Cohen's f^2 (Cohen, 1988) using the formula $f^2 = \frac{R^2_{AB} - R^2_A}{1 - R^2_{AB}}$, where R^2_{AB} represents the R^2m of the full model including the predictor of interest and R^2_A is the R^2m of the model without the predictor of interest.

Finally, we ran two exploratory analyses to investigate if there are effects of overall language similarity above and beyond the effects of word-level similarity. The first exploratory question stemmed from the possibility that learners of more similar languages may be more sensitive to using word-level phonological similarity as a strategy to support their learning. The predictor of interest was therefore a two-way interaction between word-level Levenshtein similarity score and overall language similarity. A positive interaction would indicate that learners of more similar languages showed a stronger effect of word-level phonological similarity on vocabulary acquisition order. To avoid the complexity of modelling a three-way interaction, we analysed only words where the AL TE was known/produced.

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The second exploratory question was whether the observed effects of vocabulary advantages in children learning more similar languages is fully attributed to word-level similarity between their languages. We followed the approach used by Koutamanis et al. (2024b), excluding cognates with high similarity. As we tested many words in the present study, we were able to apply a stringent criterion of Levenshtein similarity score = 0 for defining non-cognates. We analysed the subset of concepts where at least 5 out of 7 words in the additional languages had Levenshtein similarity score of 0 with the English word, which left us with 99 concepts. As with the first exploratory model, we only analysed words where the AL TE was known/produced. The predictor of interest was overall language similarity – a positive main effect would indicate that learners of more similar languages are more likely to know or produce words with no phonological overlap.

2.2. Results

English comprehension. Figure 2 shows the predicted likelihood for understanding a given English word, as derived from the binomial generalised linear model with English comprehension as the dependent variable. Phonological similarity was split into three categorical levels for visualisation purposes only (*low*: lower than 0.5 SD from the mean; *mid*: between −0.5 and 0.5 SD from the mean; *high*: more than 0.5 SD from the mean). There were 1,037 pairs in the *low* category, 541 pairs in the *mid* category, and 529 pairs in the *high* category. All word pairs in the *low* category had a Levenshtein similarity score of 0.

As predicted, it was more likely for toddlers to understand an English word if they also understood the TE in their AL. We see differences in the effect of phonological similarity between words where the AL translation equivalent was known and those where the AL TE was not known, supported by a positive interaction between AL TE comprehension and phonological similarity in the model coefficients (Table 2). This positive interaction contrasted with the negative main effect of phonological similarity. To probe this negative

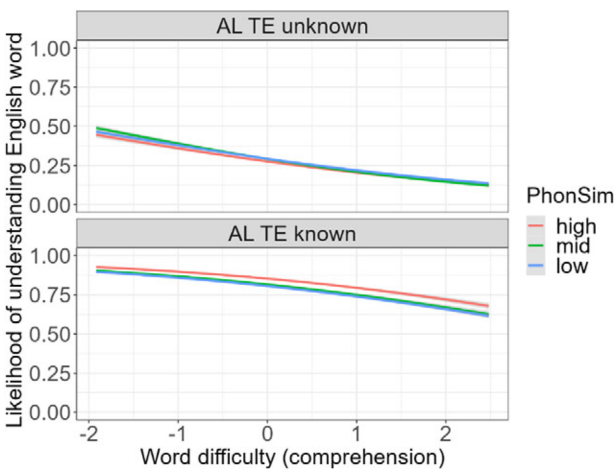

Figure 2. Plot visualising model predictions for the generalised linear model of English comprehension, with lines of best fit showing the probability of words being understood depending on word difficulty. Coloured lines represent levels of phonological similarity (PhonSim) and plots are faceted by whether or not the TE is also understood.

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Table 2. Model coefficients for the full generalised linear mixed-effect model of English comprehension, with age in months, English exposure, AL TE knowledge, word difficulty and phonological similarity as predictors, an interaction between English exposure and phonological similarity, and an interaction between AL TE knowledge, and phonological similarity

Predictor	Estimate	Std Error	*z*	*P*
(Intercept)	−0.37	0.07	−5.19	<0.001
Age	1.63	0.06	24.95	<0.001
Word difficulty	−0.96	0.03	−31.56	<0.001
Frequency	0.20	0.03	6.47	<0.001
English exposure	0.65	0.07	9.81	<0.001
AL TE comprehension	1.72	0.02	93.88	<0.001
Phonological similarity	−0.05	0.02	−3.59	<0.001
Phonological similarity: English exposure	−0.02	0.009	−2.67	0.008
Phonological similarity: AL TE comp.	0.22	0.02	12.90	<0.001

main effect, we ran a supplementary model in which only word pairs where the AL word was unknown were analysed. Findings of a similar negative main effect of phonological similarity ($z = -2.17$, $p = 0.03$) in this supplementary model supported the interpretation that, in the absence of cross-linguistic facilitation, word pairs with higher phonological similarity were more difficult to learn. It is less clear why there was this negative relationship. It seems unlikely that this effect was directly caused by the degree of phonological similarity. Instead, there may be other features of the words which were not fully captured by our covariate of word difficulty, which made the cognate words in our sample more difficult to learn than the non-cognate words. For example, there was a significant correlation between phonological similarity and length of the English word ($r = 0.13$). There may be other incidental correlations between phonological similarity and other word features that can affect word acquisition difficulty.

For our second research question, the negative interaction effect between phonological similarity and toddler's English exposure indicates that toddlers who heard less English showed a larger difference between cognates and non-cognates for English comprehension. We removed each interaction from the model to test the unique contributions of the interactions. The model without the interaction between English exposure and phonological similarity had a marginal R^2 of 0.50. Adding the interaction improved the AIC of the model (Chisq = 7.05, p = 0.00703). However, it decreased the R^2 by 0.0001. We interpret this as meaning that the interaction with English exposure did not explain unique variance in a model that already includes the interaction between phonological similarity and AL TE knowledge.

The model without the interaction between AL TE comprehension and phonological similarity had a marginal R^2 of 0.50. Adding the interaction improved the AIC (Chisq = 169.04, $p < 0.001$) and also increased R^2 by 0.0009. As such, the interaction between AL TE comprehension and phonological similarity explained unique variance in the model even after accounting for all other variables and interactions (Cohen's $f^2 = 0.002$).

English production. Similar patterns were found for English production. Figure 3 visualises the model estimates for English production. Again, we see the differing effect of

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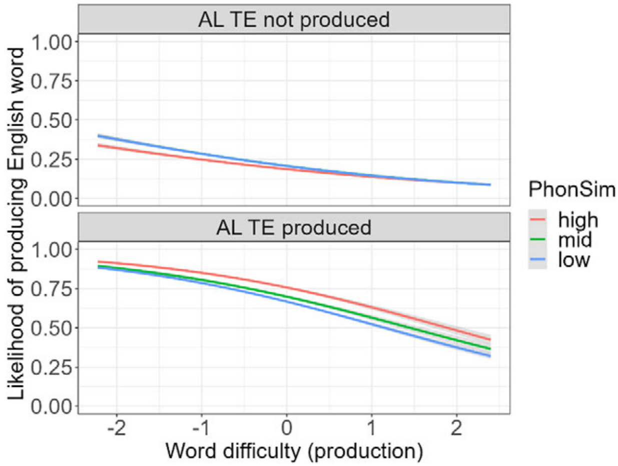

Figure 3. Plot visualising model predictions for the generalised linear model of English production, with lines of best fit showing the probability of words being produced depending on its word difficulty. Coloured lines represent levels of phonological similarity and plots are faceted by whether or not the TE is also produced.

Table 3. Model coefficients for the full generalised linear mixed-effect model of English production, with age in months, English exposure, AL TE knowledge, word difficulty and phonological similarity as predictors, an interaction between AL TE knowledge and phonological similarity, and an interaction between English exposure and phonological similarity

Predictor	Estimate	SE	*Z*	*P*
(Intercept)	−2.46	0.08	−29.33	<0.001
Age	2.44	0.08	31.07	<0.001
Word difficulty	−1.16	0.04	−33.96	<0.001
Frequency	0.21	0.03	6.27	<0.001
English exposure	0.73	0.08	9.35	<0.001
AL TE production	1.27	0.02	59.88	<0.001
Phonological similarity	−0.01	0.014	−0.70	0.48
Phonological similarity : English exposure	−0.01	0.01	−1.36	0.17
Phonological similarity: AL TE prod.	0.28	0.02	15.43	<0.001

phonological similarity between words where the AL TE was also produced and those which were not. The interaction between phonological similarity and AL TE production was positive and significant (Table 3). The model without the interaction between AL TE production and phonological similarity had a marginal R^2 of 0.56. Adding the interaction improved the AIC (Chisq = 243.87, $p < 0.001$) and increased the R^2 by 0.0003. As such, the interaction between AL TE production and phonological similarity explained unique variance in the model even after accounting for all other variables and interactions (Cohen's $f^2 = 0.0007$).

Effect of language-level similarity. To investigate whether there was an effect of language pair beyond word-level phonological similarity, we ran exploratory analyses with language similarity as a predictor and an interaction between language similarity and word-level phonological similarity. While the main effect of language similarity was significant for both comprehension ($z = 3.31$, $p < 0.001$) and production ($z = 2.98$, $p = 0.003$), there was no significant interaction for either comprehension ($z = -0.18$, $p = 0.86$) or production ($z = -0.28$, $p = 0.78$). In the second set of exploratory models, only word pairs with Levenstein similarity of 0 were analysed. There was a positive main effect of language similarity for both comprehension ($z = 2.51$, $p = 0.012$) and production ($z = 2.61$, $p = 0.009$).

3. Study 1: Discussion

Study 1 provided support for the prediction that toddlers are more likely to understand and to produce cognate words over non-cognate words after controlling for word difficulty. The cognate facilitation effect was stronger for words where the toddlers also knew the TE. In the absence of AL TE knowledge, there was a slight advantage of non-cognates over cognates for comprehension, possibly due to other properties of the words that affected its difficulty, like word length or complexity, that were not fully captured by the covariates of word difficulty and frequency. This pattern was also found by Pérez et al. (2010), where English-dominant Spanish-English bilingual children had better performance for non-cognates in an English receptive vocabulary task.

The cognate facilitation effect was stronger in toddlers for whom English was their less-dominant language, but this interaction failed to contribute unique variance to the model. We theorise that the L1–L2 imbalance in the strength of the cognate advantage for vocabulary learning can be attributed to children knowing more words in their L1, thus better facilitating the acquisition of cognates in their L2.

The exploratory analysis to test whether overall language similarity exerted an additional effect on the cognate facilitation effect showed significant results for the main predictor of language similarity but not an interaction. Children learning more similar languages had a small advantage over those learning more distant languages, but there was no support that similarity between their languages made children more sensitive to word-level similarity. The second exploratory analysis, where only word pairs with Levenshtein similarity score of 0 were analysed, indicated that the positive main effect of language similarity may not be fully attributed to word-level similarity. Children of more similar languages showed better vocabulary knowledge even for words defined as having no phonological similarity. These latter results replicate that of Koutamanis et al. (2024b), who found a similar pattern for expressive vocabulary tested using a picture naming task. Word pairs from closer languages may have greater similarities on the phonetic or morphological level than word pairs from more distant languages, leading to better performance even in the absence of clear phonological similarity. Another study supporting this idea that phonological similarity may not be the only cross-linguistic factor at play for vocabulary acquisition was Floccia et al. (2018), who found that language similarity as defined by word order typology and morphological complexity predicted vocabulary size in comprehension. However, it is also possible that our measure using Levenshtein distance underestimates the phonological similarity of the word pairs, and there is variation between words that is not sufficiently captured by the measure. Phonological similarity in the form of gradient phoneme changes, for example, the relative closeness of

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minimal pair phonemes /p/ and /b/ (as in *pat* and *bat*) as compared to the distance of phonemes /p/ and /ɹ/ (as in *rat*) may explain the effect of language similarity found in the second set of exploratory models.

The findings in Study 1 support the hypothesis that word-level phonological similarity facilitates infant vocabulary trajectories when the TE is in the infant's lexicon. One limitation in the use of cross-sectional data is that we cannot be sure that the patterns observed reflect the acquisition trajectory of TEs. It is possible that the TEs in our analysis were incidentally acquired in parallel, and not that learning one word in a pair facilitates the acquisition of the other word. By using analyses of longitudinal vocabulary growth, we can better study the acquisition of TEs over consecutive time points. This analysis is reported in Study 2.

4. Study 2: Longitudinal data

The longitudinal analyses in Study 2 acted as confirmatory analyses to our hypothesis that cognate facilitation occurs only when the learner has existing knowledge of the cognate word's TE. We conducted analyses on longitudinal data collected from a subset of families in Study 1. We grouped the data into pairs of consecutive survey responses for each child, with the earlier time point defined as T(N) and the subsequent one as T(N+1). We compared vocabulary knowledge at T(N) and T(N+1). We analysed word pairs that were either (1) understood/produced as a singlet at T(N), or (2) not understood/produced at T(N). For example, if a child knew the English word *fish* but not its Dutch translation *vis*, they were considered to know the word pair as a singlet. If the child knew neither *fish* nor *vis*, they were considered not to know the word pair. We investigated the likelihood that a word would be learned by T(N+1), dependent on its cognate status and whether the TE was known at T(N). Under our hypothesis that cognate facilitation relies on prior knowledge, we expected that if a child knew the English words *fish* and *duck* at T(N), they would be more likely to have learned the Dutch word *vis* ("fish"; cognate) than *eend* ("duck"; non-cognate) at T(N+1). In contrast, we expected the child to be equally likely to learn *vis* and *eend* by T(N+1) if they did not know *fish* nor *duck* at T(N).

4.1. Methods

Participants. The sample was a subset of 125 families from Study 1 who contributed longitudinal data for one child each. These families contributed between two and seven data points for the same child, with the total number of completed survey responses totalling 398.

The surveys were sent to parents at 2-month intervals while their child was between 1;0 and 3;0 years of age, but as parents completed the survey in their own time and may not answer every survey sent to them, the interval between consecutive longitudinal survey responses varied. Each follow-up survey was accessed via a unique link that allowed the researcher to link the new response to previous responses for the same child. Families were sent e-gift vouchers of £5/€5 or a child-sized t-shirt for each completed survey. Follow-up surveys that were completed more than five months after the previous response were excluded. We also removed children whose language environment changed drastically between two consecutive time points (defined as having more than a 25% increase or decrease in English exposure) from the analysis. In the final sample, the interval between responses ranged between 1.3 months and 4.9 months. The mean interval between time points was 2.8 months

(SD = 0.82). Child's age at T(N+1) ranged from 1;3 to 2;11 years old, with mean of 2;0. After exclusions, out of the 125 families, 60 families contributed two data points, 33 contributed three, 17 contributed four, 11 contributed five, and 4 contributed six data points.

Demographics and language exposure questionnaires. For longitudinal follow-ups, we collected a simplified demographics and language exposure questionnaire. Child's date of birth was collected to check that the parent was answering the questionnaire for the same child. Parents gave an estimate of their child's overall exposure and exposure in the home for their language(s) as of each time point, to allow us to monitor changes in exposure over time. The language exposure of T(N+1) was used in the analyses.

Vocabulary inventories. The vocabulary inventories in longitudinal follow-ups were identical to the inventories in Study 1. The CDIs in English and AL were presented immediately following the language exposure questionnaire and counterbalanced for order. Parents were not shown their previous responses.

Analysis plan. We tested increases in word knowledge between T(N) and T(N+1) across both languages. An increase in word knowledge was when a word previously unknown in both languages (TN-unknown) became a singlet or a doublet by T(N+1), or when a word pair that was a singlet at T(N) (TN-singlet) became a doublet.

Word pairs that were already doublets at T(N) were not included in the analysis. Cases that showed a decrease in word knowledge, *i.e.*, reported to be known at T(N) but unknown at T(N+1) were excluded as reporting errors. As respondents were not given access to their previous answers when completing longitudinal follow-ups, a small level of reporting error was expected. Such trials made up 9% of comprehension items and 5% of production items. The larger percentage of errors for comprehension was unsurprising, as parents typically find it harder to estimate comprehension than production.

We used a binomial generalised linear model. The dependent variable was whether a previously unknown word in the pair was learned by T(N+1). In our base model, we included five predictors as main effects, closely matched to the model used for the cross-sectional sample – phonological similarity, word difficulty, frequency, word status at T(N) (whether the toddler knew the word as a singlet or not known), English exposure at T(N +1), age at T(N+1) and the length of the time gap between T(N) and T(N+1) in months. All continuous predictors were centred on the mean and scaled by SD.

The predictor of language exposure percentage, which was included in the models in Study 1, was omitted from the longitudinal models as the predictor failed to reach significance in any of the longitudinal models. The lack of significance for this predictor was expected, given that measures of dual-language vocabulary as analysed in Study 2 are known to be less sensitive to language exposure effects, compared to single-language vocabulary measures as in Study 1. Unique to the longitudinal models, a predictor for the time gap between longitudinal follow-ups was added to account for variability in the time elapsed between survey responses.

We also examined for an interaction between phonological similarity and word knowledge at T(N). The effect of the interaction was tested by comparing the marginal R^2 between models with and without the interaction. Cohen's f^2 was calculated from R^2. Random slopes for T(N) word status were added to the random effects structure for participants and concepts.

The model syntax was specified as below in R:

$$\text{glmer}(\text{learnt\_T}(\text{N}+1) \sim \text{age} + \text{time\_gap} + \text{T(N)\_word\_status} + \text{word}$$
$$\text{\_difficulty} + \text{frequency} + \text{phon\_similarity} + \text{T(N)\_word\_status} :$$

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$$\text{phon\_similarity} + (1 + \text{TN}|\text{participant}) + (1 + \text{TN}|\text{concept}))$$

We predicted that cognates would be more likely to be learned at T(N+1) than non-cognates, but only if one of the words was already known at T(N). Statistically, this pattern would manifest as a significant positive interaction effect in the model.

Exploratory analyses were conducted by adding additional predictors and interactions to the model: First, we included a predictor of child's language dominance because we expected balanced bilingual children to know more doublets than bilingual children who were dominant in one language. English exposure percentage at T(N+1) was centred on 50% and then converted to absolute values. A language dominance value of 0 indicated balanced input; the higher the value, the more the child was dominant in one language over the other. We expected that language dominance would also influence whether children prefer to learn new concepts or TEs. A child who was mostly dominant in English should be more likely to learn a new English word than to learn a TE in their AL. We therefore examined for an interaction between language dominance and T(N) word status to test this prediction.

Secondly, we included a predictor of child's vocabulary size at T(N) because previous work by Tsui et al. (2022) suggested that children's preference for TEs shifts with their vocabulary size. Vocabulary size was centred on the mean and scaled by SD. We examined for an interaction between vocabulary size and T(N) word status to test the predictor's effect on TE preference. Finally, we examined the interaction between word difficulty and T(N) word status. Words that are easier may see a higher growth rate of new concepts, while more difficult words may be facilitated by TEs.

To identify the unique variance contributed by the added predictors and interactions, they were added one at a time to the model and compared using AIC and marginal R^2.

4.2. Results

Comprehension. A total of 40,196 word pairs were analysed for comprehension, from 297 unique concepts. Of these pairs, 27,974 were unknown at T(N) and 12,222 were singlets at T(N). As predicted, when one word was already understood at T(N), words pairs with higher phonological similarity were more likely to show an increase in word knowledge between consecutive time points than dissimilar ones (Figure 4). This observed pattern was supported by the significant positive interaction of word knowledge at T(N) and the word's phonological similarity (Table 4), indicating that the effect of phonological similarity was larger for words known as singlets at T(N) than words not known at T(N). A child who knew both "fish" and "duck" at the earlier time point T(N) was more likely to have learned Dutch "vis" (fish; high similarity) than "eend" (duck; low similarity) by the subsequent time point T(N+1) (Cohen's $f^2 = 0.002$). The main effect of phonological similarity was not significant, suggesting that cognates were not easier to learn than non-cognates overall. The model suggests that existing knowledge of a TE supports the easier acquisition of cognate words over non-cognate words, confirming observations from the cross-sectional data.

Unexpectedly, the main effect of T(N) word comprehension was not significant, suggesting that there may be no TE preference. This finding contrasted with the strong effect of AL TE comprehension observed in the cross-sectional data and merited further investigation. Visualisations of the data suggested that there was large variation in the effect of singlets across participants and across word pairs. We conducted exploratory

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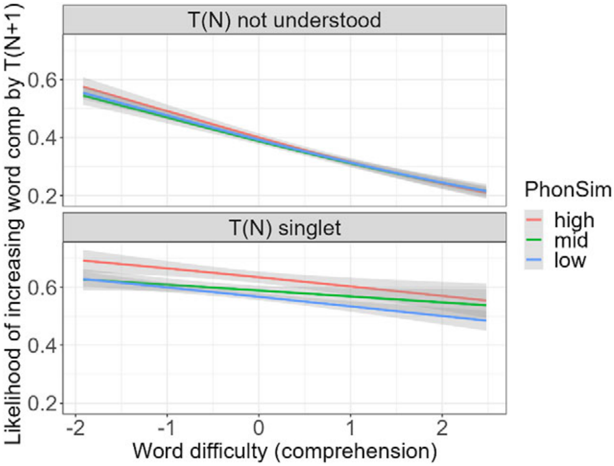

Figure 4. Model predictions for the likelihood of a word to be learned between T(N) and T(N+1), with word difficulty on the x-axis, split by phonological similarity and faceted by whether the word was a singlet or not understood at T(N). Grey bars indicate standard error.

Table 4. Model coefficients for the generalised linear mixed-effect model for comprehension at $T(N+1)$

Predictor	Estimate	SE	z	p
(Intercept)	1.02	0.16	6.44	<0.001
Age at T(N+1)	−0.08	0.10	−0.82	0.41
Time gap	0.57	0.13	4.36	<0.001
Word difficulty (comp)	−1.02	0.04	−24.64	<0.001
Frequency	0.19	0.04	5.20	<0.001
Word comprehension at T(N)	−0.21	0.17	−1.28	0.20
Phonological similarity	0.002	0.02	0.07	0.95
Dominance at T(N+1)	−0.12	0.14	−0.85	0.40
Vocab size at T(N)	1.54	0.11	14.20	<0.001
T(N) comprehension : phonological similarity	0.19	0.04	5.18	<0.001
T(N) comprehension: dominance	−0.0210	0.147	−0.14	0.89
T(N) comprehension: vocab size	−0.568	0.0900	−6.32	<0.001
T(N) comprehension: word difficulty	0.555	0.0478	11.60	<0.001

analyses on the interactions between T(N) word comprehension and language dominance, vocabulary size, and word difficulty to investigate if any of these factors explain this variation. Table 5 shows the model comparisons as the predictors and interactions were added one at a time. Neither language dominance nor its interaction improved the model. On the other hand, vocabulary size and its interaction with T(N) comprehension significantly improved the model (Cohen's $f^2 = 0.01$). This finding suggests that children with smaller vocabulary size had a stronger preference for TEs over new concepts than

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Table 5. Marginal R^2 and chi square comparisons on AIC for models of comprehension with increasing complexity

Model	R^2m	AIC	Chisq	p
Model 0	0.17	40,467		
T(N) comprehension: phonological similarity	0.17	40,445	23.92	<0.001
Dominance at T(N+1)	0.18	40,444	2.79	0.10
T(N) comprehension: dominance	0.18	40,446	0.0008	0.98
Vocab size at T(N)	0.23	40,534	85.97	<0.001
T(N) comprehension: vocab size	0.24	40,523	21.04	<0.001
T(N) comprehension: word difficulty	0.25	40,185	115.52	<0.001

Note: model 0: age + time gap + T(N) word status + word difficulty + phonological similarity.

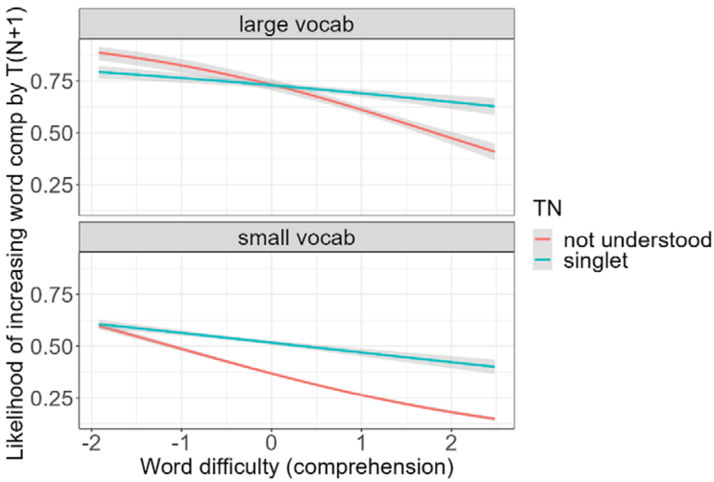

Figure 5. Model predictions for the likelihood of a word to be learned between T(N) and T(N+1), with word difficulty on the x-axis, split by whether the word was a singlet or not understood at T(N), and faceted by child's vocabulary size. Grey bars indicate standard error.

children with larger vocabulary size (Figure 4). On average, children with vocabulary size above the median learned 6.9% more TEs than new concepts (SD = 16.1%), while children below the median learned 15.4% more TEs than new concepts (SD = 22.0%).

Adding the interaction between word difficulty and T(N) word knowledge also improved the model (Cohen's $f^2 = 0.01$). On average, words that were more difficult showed a stronger TE advantage than easier words (Figure 5). Words with AoA between 12 and 13 months (2 SD lower than the mean) were 2.7% more likely to be learned when the concept was previously unknown than when it was a singlet. Meanwhile, words with AoA between 25 and 28 months (2 SD higher than the mean) were 10.6% more likely to be learned when it was a singlet.

Production. A total of 63,231 word pairs were analysed for production, from 295 unique concepts. Of these pairs, 53,783 were TN-unknown and 9,448 were

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TN-singlet. Vocabulary growth in production followed a similar pattern as comprehension, extending results found in Study 1. Again, cognates were more likely to show an increase in word production between consecutive time points than non-cognates when at least one word was already produced at the earlier time point T(N) (Figure 6). We see in the model coefficients (Table 6) that the interaction between T(N) word production and phonological similarity was significant and positive (Cohen's $f^2 = 0.001$). This finding

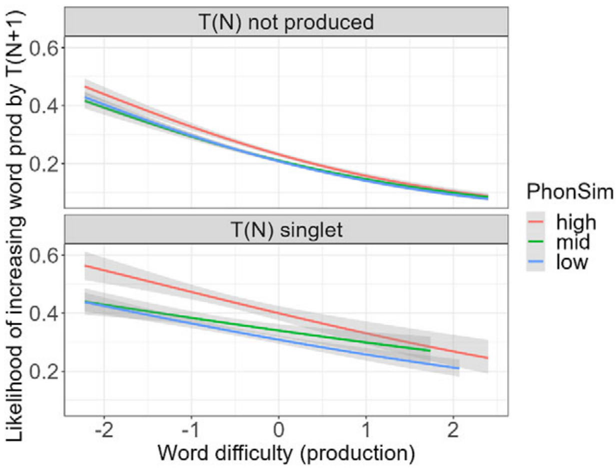

Figure 6. Model predictions for the likelihood of a word to be produced between T(N) and T(N+1), with word difficulty on the x-axis, split by phonological similarity and faceted by whether the word was a singlet or not produced at T(N). Grey bars indicate standard error.

Table 6. Model coefficients for the generalised linear mixed-effect model for production at $T(N + 1)$

Predictor	Estimate	SE	z	P
(Intercept)	−1.02	0.23	−4.47	<0.001
Age at T(N+1)	1.09	0.18	6.00	<0.001
Time gap	0.36	0.17	2.09	0.04
Word difficulty (prod)	−1.18	0.04	−27.81	<0.001
Frequency	0.20	0.04	5.20	<0.001
Word production at T(N)	−0.66	0.23	−2.88	0.004
Phonological similarity	0.072	0.02	3.75	0.0002
Dominance at T(N+1)	−0.34	0.20	−1.73	0.084
Vocab size at T(N)	0.83	0.20	4.08	<0.001
T(N) production: Phonological similarity	0.25	0.04	6.62	<0.001
T(N) production: Dominance	−0.08	0.21	−0.39	0.70
T(N) production: Vocab size	−0.52	0.12	−4.45	<0.001
T(N) production: Word difficulty	0.55	0.053	10.4	<0.001

means that the facilitatory effect of cognates on the production of new words was stronger when the child already produced one of the TEs from the word pair at T(N).

The main effect of phonological similarity was positive for production, suggesting that cognates were easier to produce than non-cognates. Nevertheless, the significant interaction indicated that prior production of singlets further boosted the advantage of cognates over non-cognates, again supporting the idea that cognate facilitation relies on existing knowledge.

Unexpectedly, the main effect of T(N) word production was negative, suggesting that new concepts are more likely to be produced than TEs of new words. As with comprehension, there was large variation in the effect of singlets across participants and word pairs.

We conducted exploratory analyses including interactions between T(N) production and child's language dominance, vocabulary size and word difficulty. Similar patterns were observed in production as were observed in comprehension. In the model coefficients (Table 6), the interactions between T(N) production with vocabulary size and with word difficulty were significant. Children with vocabulary size above the median showed a small preference for new concepts over TEs (4.4% more new concepts, SD = 20.5%), while children below the median learned 13.0% more TEs than new concepts (SD = 26.6%) (Figure 7). However, only the interaction between word difficulty and T(N) production (Cohen's $f^2 = 0.004$) significantly improved the variance explained by the model, while the interaction between vocabulary size and T(N) production (Cohen's $f^2 = -0.007$) did not. Again, language dominance was not a significant predictor. Table 7 shows the model comparisons as the predictors and interactions were added.

5. Study 2: Discussion

The longitudinal analyses further supported our hypothesis that phonological similarity across translation equivalents facilitates the acquisition of words when there is existing

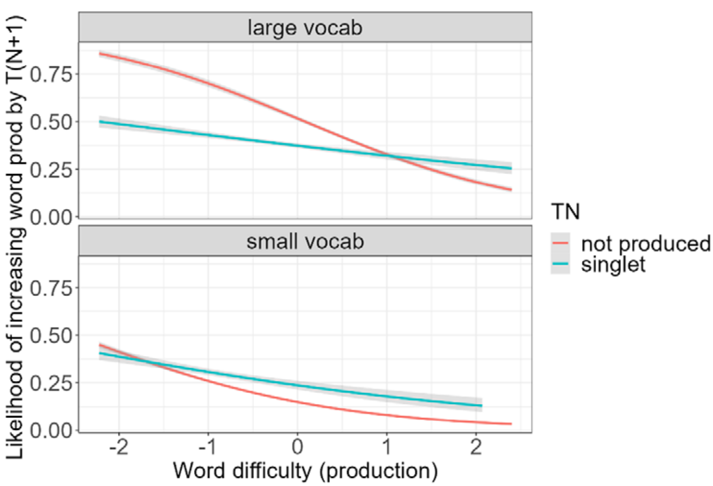

Figure 7. Model predictions for the likelihood of a word to be produced between T(N) and T(N+1), with word difficulty on the x-axis, split by whether the word was a singlet or not produced at T(N), and faceted by child's vocabulary size. Grey bars indicate standard error.

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Table 7. Marginal R^2 and chi square comparisons on AIC for models of production with increasing complexity

Model	R^2m	AIC	Chisq	p
Model 0	0.27	46,250		
T(N) production: Phonological similarity	0.28	46,213	39.26	<0.001
Dominance at T(N+1)	0.29	46,209	5.61	0.02
T(N) production: Dominance	0.29	46,211	0.23	0.63
Vocab size at T(N)	0.29	46,200	12.31	<0.001
T(N) production: Vocab size	0.28	46,192	10.08	0.002
T(N) production: Word difficulty	0.29	46,061	89.63	<0.001

Note: Model 0: age + time gap + T(N) word status + word difficulty + phonological similarity.

knowledge of the translation equivalent in one language. This interaction between phonological similarity and word status at T(N) was observed for both comprehension and production. However, an unexpected finding in the longitudinal data was a negative estimate for T(N) status in production, in direct contrast to findings in Study 1, where word pairs which were known in the AL were more likely to also be known in English. The non-significant effect of T(N) status for comprehension also suggested that there was no preference for translation equivalents when all participants were grouped together. Overall, 36.1% of TN singlets in production showed an increase in word production, as compared to 20.7% of words previously not produced. However, including random effects of participant and concept resulted in negative estimates, a case of Simpson's paradox. Simpson's paradox occurs when systematic trends exhibited by individual groups within the data disappear or reverse when the data is analysed as one large group. In this case, while the overall trend was for more translation equivalents to be learned over new concepts, many participants and word pairs exhibited the reverse pattern. We conducted analyses to investigate the participant and word-level factors that may predict individual differences in the preference of translation equivalents. Our exploratory analyses suggested that the participant-level factor of child's vocabulary size and the word-level factor of word difficulty both interacted with T(N) word status to predict the likelihood of vocabulary growth between T(N) and T(N+1). Translation equivalents facilitated the acquisition of more difficult words in the child's vocabulary but was not so useful for easy words. It may also explain the difference between children with larger or smaller vocabulary size. Children with larger vocabulary size showed a translation equivalent preference for more difficult words, and a slight new concept preference for easier words, resulting in a profile matching the neutral account.

6. Discussion

6.1. Cognate facilitation in toddlers' vocabulary

We presented findings that support the facilitatory effect of cross-linguistic word similarity on bilingual toddlers' vocabulary trajectories. Bilingual toddlers as young as 12–36 months old were sensitive to word-level cross-linguistic similarity of their languages, even when the cognates were form-similar rather than form-identical. Across both the cross-sectional sample in Study 1 and the longitudinal sample in Study 2, words with high phonological

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similarity to their translation equivalent were more likely to be learned. The effect of cognates was modulated by whether the toddler knew the translation equivalent in their other language, highlighting that the cognate advantage is dependent on cross-linguistic transfer. Additionally, effects of language dominance on cognate facilitation in vocabulary acquisition may also be attributable to translation equivalent knowledge. Bilingual toddlers may show a weaker cognate advantage for learning words in their dominant language because they are less likely to know the translation equivalents in their non-dominant language, thus not fulfilling the necessary conditions for cross-linguistic facilitation.

There may be concerns about using parent report for measuring comprehension and production of cognates by toddlers, specifically regarding whether parents can reliably recognise the language corresponding to each word. As identical cognates like German *Fisch* and English *fish* would be particularly difficult to differentiate, we excluded identical cognates with Levenshtein similarity scores of 1 from the analyses. The remaining words had at least one differing phoneme, and therefore should be more easily differentiated. However, infants' productions are often not precise. In parent-report vocabulary measures, including the Oxford CDI, parents are encouraged to accept different pronunciations as productions of a given word if it is sufficiently recognisable (for example, accepting "telly" instead of "television"). In a bilingual context, parents may mistake a production in one language (e.g. Dutch *vis*) as a mispronunciation of a word in the other (e.g. English *fish*). In the instructions of the English and AL CDIs, parents were told to rate each item based on whether their child knew the word in that specific language. Parents either saw the English CDI first or the AL CDI first and items were not interspersed, to encourage them to think about the languages separately. While these instructions should help avoid cases where parents overextend and report that their child knows English *fish* just because they know Dutch *vis*, it is still possible that a genuine difficulty in clearly determining the language that a specific word belongs to may overinflate reports of infant vocabulary. This methodological issue is unfortunately difficult to overcome. As previously mentioned, we attempted to reduce this effect by excluding identical cognates from the analysis. Additionally, the choice of modelling phonological similarity as a continuous predictor was also meant to reduce concerns that any observed effects were fully driven by cognates with very high similarity.

6.2. (Dis)preference for translation equivalents

The preference account of translation equivalent acquisition predicts that children are more likely to learn translation equivalents than new concepts. In Study 2, we found that word comprehension at T(N) was not significant for predicting word comprehension at T(N+1), instead consistent with the neutral account where there is no preference for learning translation equivalents or new concepts. For production, there was in fact, on average, a preference for learning words for new concepts.

We noticed large individual differences for whether a child showed a preference for learning translation equivalents or learning new concepts. This observation led us to conduct exploratory analyses to investigate the factors that may explain the variation across participants and word pairs. We found that children with smaller vocabulary sizes showed a stronger preference for translation equivalents than children with larger vocabulary size. This finding is consistent with Tsui et al. (2022)'s findings that children with a smaller vocabulary size (<300 words) showed patterns more consistent to the preference account than those with larger vocabulary size. In comprehension, we replicated their findings that children with larger vocabulary sizes (more than 374 words in total

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vocabulary in comprehension, the median vocabulary size in our sample) showed no preference for translation equivalents over new concepts. In production, we found that while children with smaller vocabulary size (<127 total vocabulary in production) showed a small preference for translation equivalents, children with larger vocabulary size showed a preference for new concepts. Developmental changes in the rate of vocabulary growth may explain this difference between groups. We theorise that bilingual children start with a preference of translation equivalents. When learning a new word, learners must familiarise themselves with the word form (phonology or orthography), and also its meaning. For learners of two languages, translation equivalents share their meaning, allowing word forms to be mapped onto the same concept node. Mapping a new word form to an existing concept may be cognitively easier than learning a new concept, leading to an early preference for learning translation equivalents. However, this preference for translation equivalents is later masked by a rapid increase in new concepts. The age range reported in this article (1;0 to 3;0 years old) includes a period that has been associated with a rapid acceleration of vocabulary growth, referred to as the vocabulary spurt (Bloom, 1973). Plunkett et al. (1992) offered a computational account that posits an acceleration in the acquisition of new concepts as an explanation of the vocabulary spurt. Bilingual children may show an earlier vocabulary spurt in their dominant language than their nondominant language (Gómez Díaz et al., 2024), thus resulting in faster acquisition of words in one language, which could manifest in the data as a preference for learning new concepts instead of translation equivalents.

Additionally, the acquisition rate of new concepts varied across words of different difficulty. Words that were more difficult showed a stronger translation equivalent advantage than easier words. We propose that this pattern may be attributed to similar mechanisms that explain links between proficiency and cross-linguistic transfer. Low-proficiency second language learners benefit more from cognates than high-proficiency learners, posited to be linked to the weaker lexical representations of low-proficiency learners in their second language. Likewise, more difficult words may benefit more from translation equivalents, as more difficult words likely have weaker representations at the early stages of learning due to low frequencies in the input or higher complexity that requires more exposure to learn. Let's say, hypothetically, that a Spanish-English bilingual child has only received few input tokens of the word *old*, and subsequently formed a weak lexical representation. Having the Spanish translation equivalent *viejo* in their vocabulary may facilitate learning of English *old* through its shared conceptual representation. In contrast, the same Spanish-English bilingual child has received extensive exposure to the word *dog*, and has formed a strong lexical representation. In this latter case, there should be no effect of knowing the translation equivalent *perro*, as the exposure to the English word *dog* is already sufficient. Given two words with equivalent levels of exposure, for example the words *dog* and *car*, the child should be equally likely to learn *dog* or *car*, even if the child knows the translation *perro* "dog" but not *coche* "car".

This effect of exposure on the manifestation of a translation equivalent advantage may also explain the differences observed between children with smaller and larger vocabularies. For children with smaller vocabulary sizes, the necessary exposure for successful acquisition has not been reached for many words in the CDI, resulting in an overall stronger preference for translation equivalents. Meanwhile, children with larger vocabulary sizes are likely to have received more extensive exposure to both easy words like *dog* and difficult words like *old*, therefore showing neither preference nor avoidance of translation equivalents. This claim could be tested empirically in future research by testing a wider range of more difficult words. We predict that children will show a translation equivalent advantage when learning words which are comparatively difficult for their stage of learning (as operationalised using vocabulary size). If this hypothesis is true, it would support the idea that children rely more on cross-linguistic transfer to support learning of words that they find difficult. Future studies on the role of translation equivalents on bilingual toddlers' vocabulary acquisition will need to take into consideration how choices of lexical items may affect manifestations of a translation equivalent advantage.

As we collected data on both comprehension and production in this study, we were able to study whether comprehension and production showed parallel trajectories. Children were more likely to learn new concepts than translation equivalents in production, while comprehension followed a neutral pattern. The different patterns may be related to the communicative function of word production – a child may understand both translation equivalents, but selectively produce one of the pair. Even when we look at the cross-sectional sample from Study 1, we find that on average, 59.7% of bilingual toddlers' vocabulary in comprehension were doublets (SD = 26.8), as compared to a lower average percentage of 32.8% doublets in production (SD = 25.1). Other studies have similarly found different patterns for comprehension and production. In De Houwer et al. (2014), while bilingual toddlers had larger total vocabulary sizes in comprehension than monolinguals at 13 months, there was no significant difference between groups in production at 13 months old nor at 20 months old. This pattern of similar total vocabulary size in production despite larger vocabulary size in comprehension for bilingual toddlers has also been reported in Siow et al. (2023). Toddlers' vocabulary production may also be influenced by context-dependent language selection, where a certain language may have stronger associations to specific contexts, therefore prompting children to produce more words in that language.

7. Conclusion

In this article, we provide both cross-sectional and longitudinal evidence suggesting that toddlers can capitalise on the strong phonological overlap between cognates to facilitate learning of translation equivalents, thus expanding their vocabulary. Notably, the cognate facilitation effect was dependent on existing knowledge of the word's translation equivalent in the other language. These findings provide support for the idea that bilingual toddlers are sensitive to both semantic and phonological overlap between words in their languages. The shared properties of the languages being learned may help toddlers learn their languages more easily. Findings from our exploratory analyses suggest that children make use of translation equivalents to support the acquisition of difficult words, particularly in the early stages of language acquisition. As children expand their vocabulary, they grow less reliant on translation equivalents, instead favouring the rapid acquisition of new concepts to expand their conceptual vocabulary size. Understanding the links between languages and their effects on bilingual vocabulary acquisition can help guide strategies for supporting bilingual vocabulary development.

Data availability statement. Data and analysis scripts are available on OSF at https://osf.io/kpu2a/.

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Author contribution. Data collection was conducted by S.S., N.G., and I.L. Data analysis was conducted by SS.

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