Photograph method fosters direct access to second-language word meaning: Direct evidence from a word-picture matching task

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Boddaert, G., Casalis, S., & Mahé, G. (2021). Photograph method fosters direct access to second-language word meaning: Direct evidence from a word-picture matching task. *British Journal of Developmental Psychology*, *39*(3), 407-423.

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Short title: Photograph method fosters conceptual links

Abstract:

This experiment was designed to investigate conceptual links directly through a word-picture matching task in children. Participants were asked to indicate between two pictures the one depicting the same concept as the newly learned L2 word (target). One of the two pictures was the target, while the other was either semantically related to it or was unrelated. To investigate whether learning methods modulate L2 word processing, two learning methods were compared: an L2-photograph method and an L1-L2 method. Results showed that learning was worse with the L1-L2 method than with the picture method. In addition, we found a semantic interference effect only with the L2-photograph method: children responded more slowly in the related condition than in the unrelated one. We interpret this result as suggesting that the picture method promotes conceptual links more than the L1-L2 method. We conclude that learning method modulated L2 word processing and L2 word meaning was not necessarily accessed through L1 mediation in the first steps of learning.

Keywords:

L2 learning, childhood, learning methods, conceptual links

1. Introduction

Mastering two or more languages is a major asset in today's society (see e.g. Grin et al., 2009), and 88% of Europeans consider that knowing foreign languages is very useful (European Commission, 2012). Nevertheless, only 54% of Europeans are able to hold a conversation in at least two languages, and 25% in at least three languages (European Commission, 2012). To enhance foreign language mastery, the European Union has set the objective that every young European should learn two languages in addition to their mother tongue (European Council, 2002; European Council, 2017). Investigating second language (L2) word learning is one of the keys to understand and, consequently, enhance the acquisition of foreign languages, since vocabulary level is strongly related to language comprehension (for reading comprehension see: Lervåg & Aukrust, 2010; Nation, 2006; for auditory comprehension: Nation, 2006; Stæhr, 2009) and is one of the best predictors of L2 comprehension (Lervåg & Aukrust, 2010).

The present study focuses on access to the meaning of newly learned words in the first stages of language acquisition at school, because this issue is underexplored. First, we discuss theoretical models describing the first stages of L2 lexical development, and how they have been developed on the basis of results obtained with late learners. Given the differences between adult and children learners that are described in the second part, it is important to check whether these models also apply in early learners by investigating L2 word processing in children, in whom no model has yet been proposed.

Models of L2 lexical development in late learners such as the Revised Hierarchical Model (RHM, Kroll & Stewart, 1994; Kroll et al., 2010) and the developmental Bilingual Interactive Activation model (BIA-d, Grainger et al. 2010) postulate that L1 and L2 words are stored in two different lexicons connected by lexical links (at least in the first steps of learning for BIA-d, see also the Shared Asymetrical Model, Dong et al., 2005 and the Modified Hierarchical Model, Pavlenko, 2009). These models postulate that L2 word processing evolves as a function of L2 proficiency, i.e. conceptual links connecting L2 words and semantic representations are reinforced as L2 learners become more proficient. This evolution implies that non-proficient L2 learners mainly use lexical-level links and access L2 word meaning through L1 mediation. As L2 learners become more proficient, conceptual links become stronger, enabling direct access to L2 word meaning. Given that the RHM and the BIA-d are based on results obtained with adults, the question is now whether they stand for children. This is critical since various factors point to differences between L2 learning in childhood and in adulthood.

The first reason to postulate differences between child and adult learners concerns the effect of the age of L2 learning on L2 word storage and processing. Even though the hypothesis of a critical period after which L2 words are stored in episodic memory instead of the same memory system as L1 words (i.e., in semantic memory; e.g., Jiang & Forster, 2001; Qiao & Forster, 2017, see also van Hell, 2020 for a discussion) is called into question (for semantic priming with newly L2 learned words, see Elgort, 2011, for a discussion see MacWhinney, 2008), the age of L2 learning influences L2 word processing (see for example the following brain imagery studies for this issue: Kim et al. 1997; Wartenburger et al., 2003). There is a consensus about a decline in L2 learning ability with age (see van Hell, 2020) and about the effect of the age of L2 acquisition on L2 word processing.

Another reason why there might be differences between the way adults and children learn an L2 is that L1 is already clearly established when an adult learns an L2, much more than in childhood (for a review see Nippold, 2016). This implies that it might be difficult for children to use the lexical level to access the meaning of L2 words, while it might be efficient for adult learners to use L1 mediation. Results obtained by Chen and Leung (1989) can be interpreted in support of this theory. They found that adult learners had better performances when they were asked to produce L2 words from L1 words (forward translation) than when they had to produce them from pictures (picture naming in L2), while the opposite pattern was observed with children. There might also be differences in experience with foreign languages between children and adults. Adults are more likely to have been exposed to foreign languages than children, especially during schooling. This might facilitate L2 learning in adults, given that a widespread idea supported by scientific data is that learning a new language is easier for learners who already know other languages (e.g., Kaushanskaya & Marian, 2009, for a review see: Cenoz, 2013). In short, given that there are differences between learning L2 during childhood and adulthood, it is important to investigate L2 word processing in children to check whether models describing L2 lexical development in late learners might also stand for them.

Comesaña et al. (2009) investigated L2 word processing in children with a translation recognition task in which participants had to judge whether the pairs of words presented (an L2 word and an L1 word) were translation equivalents. Three categories of pairs were used: correct translation, incorrect translation semantically related to the correct translation, and incorrect translation unrelated to the correct translation. These word pairs were used in order to investigate conceptual links through a semantic interference effect, that is, an increased number of errors and/or increased time for the rejection of words in the semantically related condition compared to the unrelated one (Altarriba & Mathis, 1997; Poarch et al. 2015; Sunderman & Kroll, 2006). Participants were Spanish children without any previous knowledge of Basque who learned Basque words either by L2-picture association (picture method) or by L2-L1 association (translation equivalent method). Results showed a significant semantic interference effect after a single learning session only in children who had learned the new words with the picture method (note that the cognate status modulates this effect in Comesaña et al., 2010, Comesaña et al., 2012). The authors concluded that children can directly access L2 word meaning and that the L1 mediation stage is not mandatory. Interestingly, results also suggested that the learning method modulates access to L2 word meaning since the semantic interference effect was not observed in the translation equivalent learning condition. The results obtained by Poarch et al. (2015) were also in favour of an effect of learning method on L2 word processing. In their experiment, fifth-grade children who pursued a weekly one-hour English course in a context enriched by pictures and oral exercises had longer response times and lower accuracies for semantically related word pairs than semantically unrelated ones in a translation recognition task, suggesting that they were already sensitive to L2 word meaning.

Despite the interesting results obtained by Poarch et al. (2015), there was no direct investigation of the effect of learning method on L2 word processing by comparing two learning methods. Comesaña et al., (2009) obtained results after an individual learning session, during which the experimenter corrected any errors. Nevertheless, given that these conditions are rarely possible in a school context, it is interesting to investigate whether similar outcomes can be observed in a more common context at school, i.e. when learning takes place in a group without personalised feedback. Importantly, in the translation recognition task, L1 words are used to investigate the conceptual links thought to directly connect L2 words and the conceptual system (CS), i.e. without L1 mediation. The use of L1 words is not ideal to investigate conceptual links between L2 words and the CS since L1 words are not engaged in the conceptual links connecting L2 words and CS (e.g., Grainger et al. 2010; Kroll & Stewart, 1994; Kroll et al., 2010). Furthermore, L1 words can activate connections that would not be activated without their presentation (e.g., links between L1 and the CS). Therefore, it is difficult to determine whether the activation of conceptual links is attributable to direct links between L2 and conceptual representations, or whether the L1 words facilitate this activation. A method directly investigating these links, i.e., without presentation of L1 words, would be useful, all the more as the L1 words used in the translation recognition task may activate conceptual representations independently of the L2 words.

The aim of the present study was to investigate the conceptual links through a direct test in the first stages of learning in childhood. For this purpose, a word-picture matching task was used in which a word was presented auditorily to the children and was followed by two pictures, presented simultaneously on each side of the screen. One of the two pictures represented the concept depicted by the word (e.g. the word 'gift' and a picture depicting a gift), while the other was either semantically related to the word (in half of the trials, e.g. the word 'gift' and a picture depicting a toy) or unrelated to the word (on the other half of the trials, e.g. the word 'gift' and a picture depicting a pear). Participants had to indicate the target pictures. In line with the results observed for the translation recognition task, (e.g., Altarriba & Mathis, 1997; Comesaña et al., 2009; Poarch et al., 2015; Sunderman & Kroll, 2006), the creation of conceptual links should lead to an inhibition effect in the semantically related condition in comparison with the unrelated condition. Indeed, since selecting the target picture requires inhibiting the semantic distractors, the task will be more difficult for participants who create conceptual links. The second objective of this experiment was to investigate whether the learning method modulates conceptual links. Two methods were compared: an L2-photograph method and a translation equivalent method. We hypothesised that the photograph method should promote conceptual links more than the translation equivalent method. If this hypothesis is correct, the conceptual effect observed in the word-picture matching task should be greater for the children who learned with the L2-photograph method.

2. Method

2.1. Participants

Forty third-grade students studying in two state schools took part in the experiment (age comprised between 8.25 and 10.15 years; mean age: 8.83; SD: 0.37). To determine the number of participants, we relied on previous studies (Comesaña et al., 2009; Comesaña et al., 2010; Comesaña et al., 2012). In addition, a power analysis was run with the 'simr' package (Baayen et al., 2008) to check that this value was sufficient (see 3.3 Power analysis in page 13). All participants were French native speakers and were not English bilinguals (parents also reported that their children did not take extra English lessons outside of school). They were already receiving English lessons at school, but according to their teachers, the words used in this experiment were unknown. Children were randomly assigned to one of the two groups (i.e., one for each method, 20 children in each group). Written informed consent was signed by both children and parents. The research project was approved by the local ethics committee.

2.2 Stimuli

Learning phase:

Words to be learned

Twenty-four non-cognate English words were used in this experiment. The words referred to manipulable artefacts (the list of stimuli used is available in appendix A). The mean number of letters was 5.79 (SD = 2.02). The mean number of syllables was 1.71 (SD = 0.69). The mean frequency of the words (extracted from Manulex; Lété et al. 2004) in L1 for children from first grade to fifth grade was 58.34 (SD = 128.56). The audio files were audio recordings of two English native speakers (i.e., one male and one female) reading the words. One version was used in the learning phase, while the other was used in the test phase.

Photographs used in photograph method

Twenty-four coloured photographs depicting the same concepts as the learned English words on a white background were selected from Google images. A pre-test was carried out with 10 participants (not included in the experiment) who were asked to name the photographs. The concepts depicted by the photographs were recognized by every participant: every response reflected the concept depicted by the photographs.

Word-picture matching task

For this task, each learned word was paired with two pictures. One of them depicted the same concept as the word (e.g. the word 'gift' and a picture depicting a gift, see the second column of the appendix A). The second picture was either a picture depicting a concept semantically related to the word (e.g. the word 'gift' and a picture depicting a toy, see the sixth column of the appendix A), or either a picture depicting a concept unrelated to the word (e.g. the word 'gift' and a picture depicting a pear, see the fourth column of the appendix A). In the semantically related condition, concepts were selected from results of latent semantic analysis (Landauer et al., 1998). Words referring to the concepts depicted by the pictures in the unrelated condition were matched to those in the related condition in terms of number of letters (in both groups mean = 7 and SD = 2.19, p value of t-test = 1) and frequency (mean respectively = 32.14 and 33.67, SD = 39.34 and 37.76, p value of t-test = .89). Words referring to the concepts depicted by the pictures both in unrelated and related conditions were matched as well as possible to the words in the condition where the picture depicted the same concept as the word in terms of number of letters (mean = 7.13 and SD = 1.94) and frequency (mean = 58.34 and SD = 128.56). To avoid multiple judgments for the same word, the pairs of pictures were counterbalanced across two lists. Each L2 word appeared in only one condition in each list. For instance, if an L2 word was presented with the picture depicting the same concept as the word and a picture semantically related to this word in list 1, it was associated in list 2 with the picture depicting the same concept as the word and a picture semantically unrelated to this word. The lists created were matched in terms of number of letters (p-value of t-test were .92, .47, .36 for L2 words referring to the target pictures, to the semantically related distractors, and to unrelated distractors, respectively) and frequencies (p-value of t-test were .43, .18, .16 for words referring to the target pictures, to the semantically related distractors, and to unrelated distractors, respectively).

Pictures used in the word-picture matching task

Pictures used in the word-picture matching task were different from those used in the learning phase. The pictures used were black and white pictures depicting the concepts on a white background. Forty-one pictures were extracted from the Multipic databank (Duñabeitia et al., 2018), and the 31 others were selected from Google images in order to be as close as possible to the style of the pictures extracted from Multipic.

2.3 Procedure

The experiment lasted two days. The learning phase took place the first day and participants completed the word-picture matching task the day after.

First day

Learning phase

The learning phase was composed of 9 presentations of each item. Presentations were organised by blocks, each one comprising a presentation of each of the 24 items. In each trial, a fixation cross was displayed (200ms), then a visual stimulus was displayed (5000ms), and the word to be learned was presented auditorily after 4800 ms. The auditory stimulus was presented during the presentation of the visual stimulus but after 4800 ms to enhance learning. This enabled the children to process the visual stimulus (i.e., to read the word in the translation equivalent group and to recognize the photograph in the photograph group) before the presentation of the word to be learned, and enabled them to hear the L2 word while the visual stimulus was still displayed. This was to avoid participants becoming confused and matching the word to be learned with the previous or the following visual stimulus. The type of visual stimuli presented depended on the learning method. In the translation equivalent group (TE group), stimuli were the French translation equivalents of the L2 words. A handwriting font called "freestyle script" (font size: 50) was used. In the photograph group (P group), the visual stimuli were photographs of the concepts depicted by the L2 words. The intertrial interval was 1000ms. Participants in both groups received the instruction to learn the associations between the pairs of stimuli. The learning phase took place collectively i.e., one group of 10 participants per method in both schools in a room (different from the classroom) in which chairs were arranged in a semicircle in front of a projector. Once participants had sat down, we checked that they were able to correctly see the stimuli depicted on the screen by presenting a word (for the TE group) and a photograph (for the P group).

Second day

Word-picture matching task

The word-picture matching task was composed of 24 trials. As previously mentioned, two pictures were presented simultaneously. One picture was presented on the right of the screen and the second picture on the left. One of the two pictures represented the same concept as the word (target picture), while the other was a distractor. The distractor was either semantically related to the target picture (half of the trials) or unrelated to it (other half of the trials). Each trial was organised as follows: fixation cross (200ms), white screen (50ms), L2 word presented auditorily, white screen (100ms), the two aforesaid pictures (until participants answered or 5000ms). Participants were instructed to indicate the target picture as accurately and rapidly as possible. They had to press the right 'CTRL' key to indicate that the target picture was the one displayed on the right side, and the left 'CTRL' key to indicate that it was on the left side. The intertrial interval was 1000ms. This task was carried out individually in a quiet room.

3. Results

Data were analysed in the software R (R Core Team, 2017) using a mixed model approach (Baayen et al., 2008) with the lme4 package (Bates et al., 2015).

3.1. Accuracy

Given that accuracy is a binomial variable, errors were analysed with binomial mixed models. To select the best model, a backward elimination procedure was used, the models compared and the results of the models' comparison are provided in Appendix B. The model selection procedure started with a complete model including the following random effects: (1 + Relatedness | Subject) + (1 + LearningMethod * Relatedness | Target), and these two fixed effect factors and their interaction: Relatedness between words and distractors: *related, unrelated*; Learning method: *translation equivalent, photograph*. This model failed to converge, so we reduced the random effects until the problem was resolved. The random effects used were: (1 + Relatedness | Target). According to the Akaike Information Criterion (AIC), the best model is the model with both the effect of relatedness between words and distractors: (*related, unrelated)* and that of learning method (*translation equivalent, photograph)*. The results of the parameters in this model are reported in Table 1. The complete model is shown in Table 2. In other words, there was a significant effect of learning method (mean percentage of correct responses in the photograph method: 80%, SD: 40; in the translation equivalent method: 66%, SD: 47) and of relatedness between words and distractors (mean percentage of correct responses in the unrelated condition: 77%, SD: 42; in the related condition 69%, SD: 46). Mean percentage of correct responses according to learning method and relatedness between word and distractor are reported in Table 3 (see also Appendix C).

[Insert Table 1 here]

[Insert Table 2 here]

[Insert Table 3 here]

3.2. Response times

Incorrect responses were excluded from this analysis. Response times greater than 4500ms and lower than 100ms were considered as outliers and were also excluded. To select the best model, an automatic backward elimination procedure using the function step from the lmerTest package (Kuznetsova et al., 2017) was used. The model selection procedure started with a complete model including the following random effects: (1 + Relatedness | Subject) + (1 + LearningMethod * Relatedness | Target), and these two fixed effect factors and their interaction: learning method: *translation equivalent, photograph*; relatedness between words and distractors: *related, unrelated*. As expected, the best model was the one with the following formula: RT ~ LearningMethod * Relatedness + (1 | Subject) + (Learning Method | Target). The results of the parameters in this model are reported in Table 4 (for completeness, we also reported results obtained with a maximal structure in Table 5). The fact that there is a significant interaction between learning method and relatedness indicated that the patterns were significantly different between the two groups. Therefore, we analysed the data separately for the two groups. In the photograph group, there was a significant interference effect of relatedness (the comparison of a model including the effect of relatedness to a model including no fixed effect factor showed that this model was better, $\chi2 = 9.74$, $p = .002$; results of the parameters in this model are reported in Table 6, note that using the function step led to select the same model). In the translation equivalent group, the effect of relatedness was not significant (the comparison of a model including the effect of relatedness to a model including no fixed effect factor showed that this model was not better, $\chi 2 = 0.07$, $p = .797$; results of the parameters of the model including the effect of relatedness are reported in Table 7; according to the function step the best model was the one without the effect of relatedness, see Table 8). Mean response times and standard deviation are reported in Table 9 (see also Appendix D).

[Insert Table 4 here]

[Insert Table 5 here]

[Insert Table 6 here]

[Insert Table 7 here]

[Insert Table 8 here]

[Insert Table 9 here]

3.3. Power analysis

The power analysis was run with the ‘simr’ package (Baayen et al., 2008). Based on 100 simulations, the power for the model including the interaction effect was 100% (confidence interval: 96.38 – 100). In the photograph group, the power for the model with relatedness was 91% (confidence interval: 83.60 – 95.80).

4. Discussion

The aim of this study was to directly investigate the conceptual links in the first stages of L2 learning through a word picture matching task performed the day after learning. Two learning methods were used: an L2-photograph method and an L1-L2 method. Results on accuracy showed an inhibitory conceptual effect: responses were less accurate in the related condition than in the unrelated condition in both groups. We also found a learning method effect: participants in the L2-photograph method made fewer errors than those in the L1-L2 method group. These results show that the L2-photograph method promotes more L2 word learning than the L1-L2 method, but that both methods enable direct access to L2 word meaning (inhibitory conceptual effect in both group). Nevertheless, results on response times showed a significant inhibitory conceptual effect only in children who learned new L2 words with the photograph method: they responded more slowly in the related condition than in the unrelated one. No significant semantic interference effect was observed with the L1-L2 method. According to the result, the more likely scenario is that the L1 mediation stage for accessing L2 word meaning is not mandatory. Additionally, the learning method modulates access to L2 word meaning, i.e., the photograph method fosters direct access to L2 word meaning through conceptual links. Note that this latter result is not new and has been shown with another testing method namely a translation recognition task (e.g., Comesaña et al. 2009).

The fact that our results echo the ones in Comesaña et al. (2009), obtained with different learning contexts and different testing methods, strengthens the conclusion about the effect of learning method on L2 word processing in children. Indeed, the learning method modulates L2 word processing regardless of whether learning took place in individual learning sessions with personalised feedback (Comesaña et al. 2009) or in groups without feedback. Furthermore, results showed a significant inhibitory effect with both direct and indirect method of investigating conceptual links. Indeed, as previously mentioned, in the translation recognition task, L1 words are used to investigate the conceptual links thought to directly connect L2 words and the conceptual system, while they are not engaged in these conceptual links. Moreover, L1 words can activate connections that would not be activated without their presentation (e.g., conceptual links between L1 and the CS). Therefore, it is difficult to determine with this indirect method whether the activation of conceptual links is attributable to direct links between L2 and conceptual representations, or whether the L1 words activate conceptual representations independently of the L2 words. To limit this risk, the current experiment used a direct method: a word picture matching task.

At the same time, one could argue that the effect was not a conceptual effect but rather a modality-specific effect, i.e., learning with static visual representations leads to a greater effect in a task using static visual representations. Nevertheless, the visual representations used were different: photographs were used in the learning method, while drawings were used in the test phase. Furthermore, since the conceptual effect is an inhibitory effect based on the relatedness between the words and the distractors, an effect modality (e.g., similarity between learning and test conditions) should have led to an absence of effect rather than an increase in the conceptual effect. Indeed, a visual similarity effect would have facilitated the detection of the target picture and would have led to faster responses for the correct picture independently of the distractor.

This study has some limitations. First, the number of words to be learned is rather low. Further research should involve more words to be learned, and therefore more learning sessions. As we used real words, it was not possible to make sure that each word was completely unknown by all children. Even though we limited this issue by checking with teachers that these words were unknown by children (because they had not already been taught at school and as parents reported that their children did not take extra English lessons outside of school), a given child may have happened to already know a specific word. However, this eventuality should not affect the pattern of results since children were randomly assigned to one of the two groups. A third limitation is that, although no L1 words were presented to the participants of the picture group, they might activate L1 words when processing L2 words. Nevertheless, according to the literature, this is an unlikely scenario. Indeed, to the best of our knowledge there is a consensus in the translation priming literature about the absence of priming effect from L2 primes to L1 targets (contrary to translation priming from L1 primes to L2 targets; for a review see for example Brysbaert & Duyck, 2010). This is one of the main challenges against the lexical links between L2 and L1 postulated by the Revised Hierarchical Model (Kroll & Stewart, 1994) and the developmental Bilingual Interactive Activation model (Grainger et al., 2010; for a review see for example Brysbaert & Duyck, 2010). Furthermore, if L1 words are activated during L2 word processing, how to explain that the learners in the L1-L2 method learned worse than the picture method group? Finally, a fourth limitation is that we cannot assess the long-term stability of the results, as the learning session was short.

This experiment has both practical and theoretical implications. At a practical level, there are implications for L2 learning in school since the findings demonstrate that it is possible to foster a direct access to L2 word meaning with an L2-photograph method, not only in laboratory conditions (e.g., Comesaña et al. 2009) but also when words are learned at school with an L2-photograph method. Consequently, the learning method used in school should rely as much as possible on associations between L2 words and visual representations of their meaning. At a theoretical level, the results obtained are not in accordance with the models of L2 lexical development (e.g., the Revised Hierarchical Model, Kroll & Stewart, 1994; Kroll et al., 2010, and the developmental Bilingual Interactive model, BIA-d, Grainger et al., 2010), which postulates that non-proficient L2 learners mainly use lexical-level links and access L2 word meaning through L1 mediation. Given that these models are based on data obtained with adults and that the results of our experiment were obtained with children, the current findings suggest that the models of L2 lexical development do not systematically stand for children. This hypothesis is supported by the differences between child and adult learners previously mentioned: the critical period hypothesis (e.g. Jiang & Forster, 2001; Qiao & Forster, 2017, see also van Hell, 2020 for a discussion) or at least the decline in L2 learning with age (see van Hell, 2020), the fact that an adult's L1 is already clearly established when they learn an L2, in any case much more than in childhood (for a review see Nippold, 2016), and the fact that adults are more likely to have been exposed to foreign languages than children, especially during their schooling. Further research should investigate the effect of learning method on the first stages of learning in adults to determine whether a similar effect can be observed with late learners.

In summary, this study using a direct testing protocol shows that a method based on associations between L2 words and visual representations of concepts promotes conceptual links. It also paves the way for the direct investigation of conceptual links in children through a word-picture matching task.

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Table 1. *Summary of the model for accuracy*

Predictors	b	SE b	z	p
(Intercept)	1.650	0.158	10.416	< .001
Learning Method	-0.732	0.152	-4.819	< .001
Relatedness	-0.441	0.175	-2.516	.012

Formula: accuracy ~ LearningMethod + Relatedness + (1 + Relatedness | Target).

Table 2. *Summary of the complete model for accuracy*

Predictors	b	SE B	z	p
(Intercept)	1.669	0.189	8.811	< .001
Learning Method	-0.764	0.227	-3.359	<.001
Relatedness	-0.475	0.252	-1.885	.059
Learning Method * Relatedness	0.057	0.306	0.187	.851

Formula: accuracy ~ LearningMethod * Relatedness + (1 + Relatedness | Target).

Table 3. Mean percentage of correct responses (SD) according to learning method (translation equivalent, photograph) and relatedness between word and distractor (related, unrelated)

Photograph		Translation equivalent	
Unrelated	Related	Unrelated	Related
84 (37)	76 (43)	71 (46)	62 (49)

Table 4. *Summary of the model for response times*

Predictors	B	SE B	t	p
(Intercept)	1124.85	95.92	11.727	< .001
Learning Method	614.69	141.78	4.335	< .001
Relatedness	159.01	60.14	2.644	.008
Learning Method*Relatedness	-177.73	90.30	-1.968	< .05

formula: RT ~ LearningMethod * Relatedness + (1 | Subject) + (Learning Method | Target)

Table 5. *Summary of the complete model for response times*

Predictors	B	SE B	t	p
(Intercept)	1141.47	50.73	22.503	< .001
Learning Method	633.87	72.80	8.707	< .001
Relatedness	157.05	71.84	2.186	.032
Learning Method*Relatedness	-212.02	106.50	-1.991	.047

formula: RT~ LearningMethod * Relatedness + (1 + Relatedness | Target)

Table 6. *Summary of the model for response times for the photograph group*

Predictors	B	SE B	t	p
(Intercept)	1125.90	62.72	17.953	< .001
Relatedness	160.14	50.95	3.143	.002

formula: RT ~ Relatedness + (1 | Subject)

Table 7. *Summary of the model including the effect of relatedness for response times for the translation equivalent group*

Predictors	B	SE B	t	p
(Intercept)	1735.76	128.39	13.520	< .001
Relatedness	-20.30	78.68	-0.258	.797

formula: RT ~ Relatedness + (1 | Subject) + (1 | Target)

Table 8. *Summary of the best model according to the function step for response times for the translation equivalent group*

Predictors	B	SE B	t	p
(Intercept)	1726.42	123.28	14	< .001

formula: RT ~ (1 | Subject) + (1 | Target)

Table 9. Mean response times in ms (SD) according to learning method (translation equivalent, photograph) and relatedness between word and distractor (related, unrelated)

Photograph		Translation equivalent	
Unrelated	Related	Unrelated	Related
1141 (417)	1298 (658)	1773 (897)	1718 (790)

Appendix A. Stimuli and characteristics of stimuli used in experiment

Learned word	Translation equivalent in L1	Word frequency of the L1 translation equivalent*	Unrelated distractor	Word frequency of unrelated distractor*	Semantically related distractor	Word frequency of semantically related distractor*
banknote	billet	31.83	montgolfière	3.57	portefeuille	8.47
camcorder	caméra	15.01	épée	35.19	télé	38.77
door	porte	628.45	chapeau	190.87	fenêtre	180.53
driller	perçeuse	2.04	calculatrice	0.02	tronçonneuse	0.47
gift	cadeau	91.69	poire	29.38	jouet	30.75
hoover	aspirateur	10.45	bocal	28.34	balai	31.38
ice	glace	177.19	armure	12.04	bonbon	12.11
jug	carafe	7.84	parapluie	74.87	bouteille	75.46
keyboard	clavier	5.24	hache	38.24	piano	47.43
ladder	échelle	57.56	pansement	8.5	ascenseur	8.62
mail	courrier	29.81	canon	17.48	colis	15.94
mobile	téléphone	114.37	bicyclette	49.6	ordinateur	48.55
mower	tondeuse	6.29	passoire	4.84	brouette	8.13
paste	colle	69.93	gaufre	0.75	scotch	0.42
rake	râteau	16.57	gobelet	6.11	fourche	6.09
remote	télécommande	0.73	sablier	0.46	manette	0.45
rubbish	poubelle	16.61	bonnet	38	coffre	40.87
saw	scie	18.48	guitare	44.07	couteau	52.23
scale	balance	40.03	plume	54.53	règle	57.89
screwdriver	tournevis	7.78	carotte	36.15	marteau	37.13
shaver	rasoir	7.59	collier	46.91	ciseaux	50.81
shovel	pelle	24.12	clef	27.4	seau	31.86
swing	balançoire	11.54	boussole	9.51	toboggan	8.42
watering	arrosoir	9.03	cravate	14.51	robinet	15.38

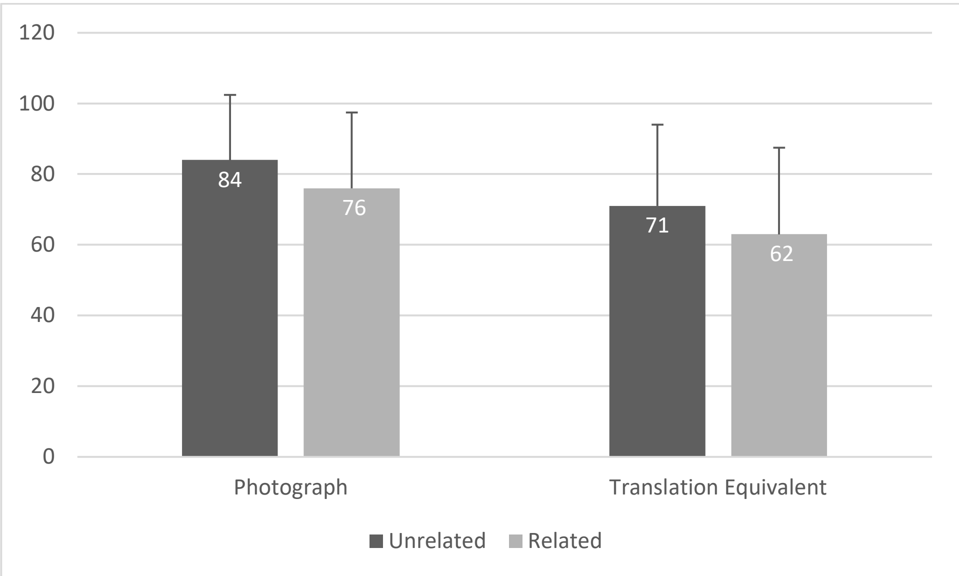
* Frequencies are presented in occurrences per million. They were extracted from the corpus for children from first to fifth grade of the Manulex (Lété et al., 2004).

Appendix B. Models used for accuracy and results of the models' comparison

Model	AIC	BIC	χ2	p
M0: accuracy ~ LearningMethod * Relatedness + (1 + Relatedness | Target)	1096.9	1130.9		
M1: accuracy ~ LearningMethod + Relatedness + (1 + Relatedness | Target)	1094.9	1124.1	0.035	.852
M2a: accuracy ~ LearningMethod + (1 + Relatedness | Target)*	1098.6	1122.9	5.710	.017
M2b: accuracy ~ Relatedness + (1 + Relatedness | Target)*	1116.8	1141.1	23.874	< .001

* Models M2a and M2b were individually compared to M1

Appendix C. Percentage of correct responses according to learning method and relatedness between word and distractor.



Appendix D. Mean response times in ms according to learning method and relatedness between word and distractor.