The Multilingual Brain: An Experimental Study

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ABSTRACT
This study investigates the organization of the mental lexicon in the multilingual brain in order to determine whether there is interaction between the lexicons of a speaker's different languages. We performed a cross-language semantic priming experiment with Dutch native speakers having varying levels of French. We analysed our data in view of three models: the independent model (Kolers, 1963), the revised hierarchical model (Kroll & Steward, 2002) and the BIA+ model (Dijkstra et al, 2002). Our results support the independent model in which there is suggested that there is no interaction between the mental lexicons of the speakers' languages.

KEYWORDS
Multilingualism, multilingualism in the brain, semantic priming, independent model, BIA+ model, revised hierarchical model.

INTRODUCTION
Multilingualism is a hot topic in current research in linguistics. Much is still unclear about the functioning of the fascinating part of the human brain that deals with linguistic input from different languages. With most of the world´s population being multilingual, researching the multilingual brain is beneficial in many ways. Studies on the multilingual brain can be adapted by teachers in (language) education globally. More profound knowledge on this human capacity opens opportunities for children independently of their linguistic background: once we know how language is stored in the brain, we can use this knowledge to create new methods in (second) language acquisition that fit the processing system at its best.

In this research, we focus on the mental lexicon: the part of the human brain responsible for memorizing and linking words and concepts. Vocabulary is one of the first steps in acquiring or learning a new language, which makes it even more interesting to know how different languages are related to each other in the brain of a multilingual speaker. The research question of this particular study is the following: 'How is the system of lexical processing organised in the multilingual brain?'. We will investigate this question with the help of a cross-language semantic priming experiment with 20 Dutch - French bilinguals. The results will be analysed according to three models of lexical processing: Kolers' Independent Model, the Revised Hierarchical Model of Kroll and Steward and Dijkstra's BIA+ model.

MODELS OF LEXICAL PROCESSING
Human linguistic knowledge is stocked in commonly called 'the mental lexicon' (see Farahian, 2011 for a detailed description). In this mental lexicon, the brain stores semantic, syntactic, phonological and morphological information of words. The assumption of the existence of such a system raises the question of what this mental lexicon would look like for multilingual speakers. In this study we selected the three most influential systems to lead our research.

The Independent Model
The Independent Model as described by Kolers (1963) postulates that there is a separate mental lexicon for every langue a person speaks. This means that there is no influence of the system of Language B whilst processing linguistic input of Language A.

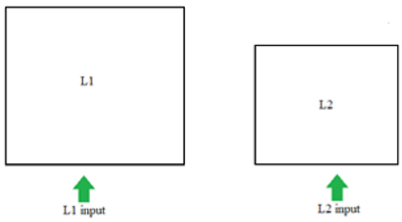


Figure 1: a possible representation of the Independent Model

The BIA+ model
The Bilingual Interactive Activation (BIA+) model (Dijkstra et al, 2002) offers different views on multilingual language processing. The current model expects all linguistic knowledge a speaker possesses to be stocked in the same mental area of the brain. Linguistic input in Language A is thus processed by a neutral system that stocks Language A as well as Language B.

We illustrate the functioning of this model with an example: a Dutch-French multilingual speaker who hears the word *magasin* 'store' will not only activate the meaning of the French word, but also the Dutch phonological equivalent *magazijn* 'stockroom'. The semantic information of both words will be stocked in the working memory until the speaker choses the right concept.

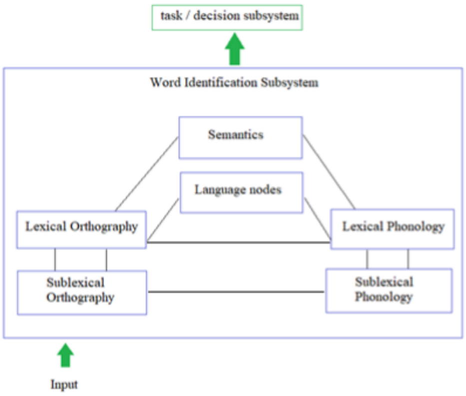


Figure 2: Dijkstra et al (2002) BIA+ model

The revised hierarchical model

Kroll and Steward (2002) proposed a general model of language processing which can be described as a mix between the two models described above. Their model is inspired by sequential language acquisition and it states that language processing differs depending on the level of fluency of the speaker. According to Kroll and Steward, there are lexical representations, information on wordform, and conceptual representations, the concepts of meaning of the words. The model describes a separate lexicon for lexical representations of words for a speaker's L1 and L2, and shared conceptual representations for the two languages.

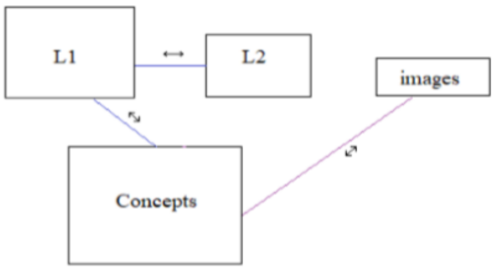


Figure 3: Kroll & Steward (2002) Word Association

Starting his L2 acquisition, a speaker directly links L2 words to the translation equivalents in the L1. This means that this process does not involve direct knowledge of conceptual meaning of the L2 input. The speaker accesses the conceptual representations of the input via the L1.

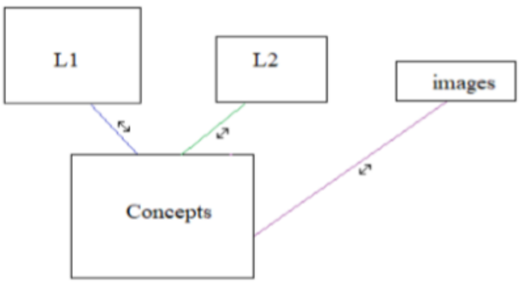


Figure 4: Kroll & Steward (2002) Concept Mediation

Progressively, a speaker becomes more fluent in his L2. This development changes the structure of L2 processing according to the Revised Hierarchical Model. A higher level of fluency creates a direct connection between L2 lexical representations and conceptual representations. This means that a speaker can now access conceptual representations directly via L2 input.

SEMANTIC PRIMING

Semantic priming is the change in performance in a cognitive or perceptual task caused by earlier experiences (McNamara, 2005). In our experiment, we will be using semantic priming to decide which of the described models represents best the functioning of the multilingual brain. In a semantic priming experiment, there is a target and a prime. The participant first sees a prime word (e.g. *cat*), followed by a target (e.g. *dog*). When there is a lexical semantic relation, i.e. a relation at the level of conceptual meaning, the reaction time of pronouncing the target is shown to be faster as compared to a situation in which the prime is not semantically related to the target. The functioning of this phenomenon is explained by Spreading Activation Models (see Collins & Loftus, 1975). The visual or auditive representation of a word, e.g. *cat*, activates its internal, conceptual, representation. The activation of the conceptual representation of cat also activates related concepts, like dog. This model explains the functioning of semantic priming: if a target word is semantically related to the prime word, the prime has already partially activated the target word which leads to a faster reaction time in a semantic decision task.

METHOD

This study investigates the existence of semantic priming in a cross-language semantic priming experiment. The Dutch French bilinguals briefly see a French priming word, before they have to name an image in Dutch.

Participants

The participants are 20 Dutch French bilinguals studying at Leiden University. They have been separated in two groups: a high proficient group and a low proficient group. We made this division with the help of the LexTALE (Brysbaert, 2013). The LexTALE is a French vocabulary test which determines the proficiency level of the test takers. The LexTALE consists of 56 words and 26 non-words, the participants have to decide if the word string shown on the screen is an existing word or not. We translated the scores of the LexTALE to a language proficiency score based on a classification of Lemhöfer and Broersma (2012). The low proficient group obtained scores beneath 59%, giving a B1 or lower proficiency, according to the classification. The high proficient group scored above 60%, which equals a proficiency above B1.

Stimuli

For this experiment, we used 50 target words. Every word was preceded by a semantically related prime word, or a control word. The stimuli were all high frequent words (based on Lexique.org, a database calculating the frequency of 135.000 French words) with a maximum of two syllables.

Target	Prime word	Control word
mond	nez	roue
arm	jambe	sirène
glas	eau	portable
kat	chien	peignoir

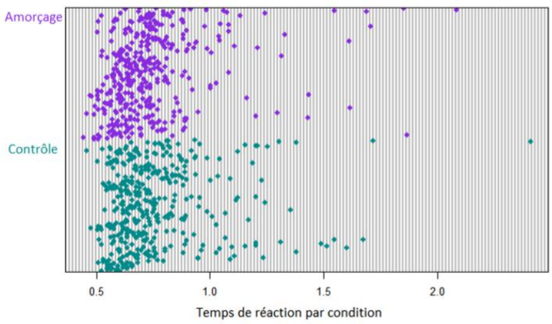
Table 1: Examples of stimuli

Experimental procedure

The experiment was a naming task in which the participants had to name an image that appeared on the screen. The image was preceded by a semantically related prime, or by a control word. We tested backwards priming, which means that the priming word was presented in French (the L2), and that the participants had to name the image in Dutch. This prime direction has been chosen to be able to make a distinction between the three different models. The Stimulus Onset Asynchrony (SOA) was 200 ms, which means that the priming word appeared 200 ms before the target image and that the prime was shown for 150 ms to obtain optimal priming results (Hutchison et al. 2001).

RESULTS

The data were analysed with the ANOVA test (Iversen, 2011). In a general analysis of the data, we compared the reaction times of the participants without distinguishing them in proficiency. The results are visualized in graph 1.

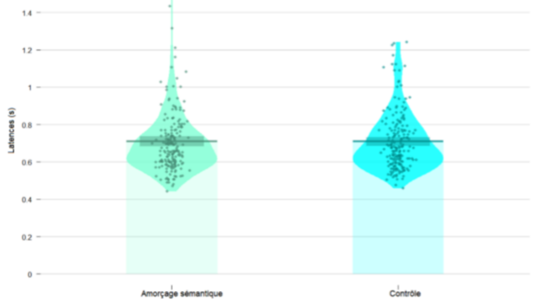


Graph 1: reaction time divided by condition

The results show that there is no general semantic priming effect in either of the two conditions. The mean reaction time in a prime situation (N=390) is 734 ms. The mean reaction time in a control situation (N=397) is 752 ms. The 18 ms difference between the two conditions is not significant (*p*=0,25).

Results for low proficient speakers

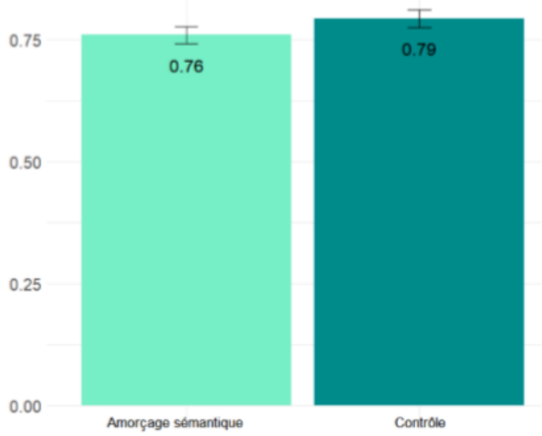
For the low proficient speakers, the mean reaction time in a prime situation (710ms) was not significantly faster than the mean reaction time in a control situation (710ms). This is shown in graph 2.



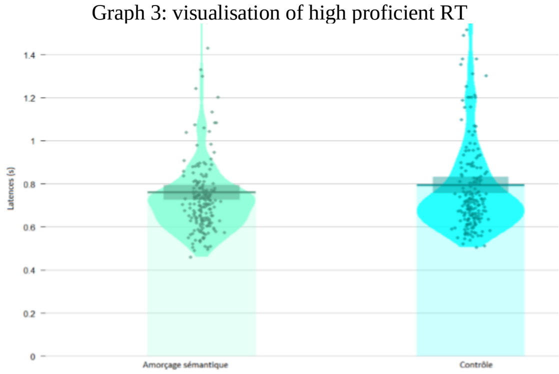
Graph 2: spreading of reaction times

Results for high proficient speakers

We find similar results for the group of high proficient speakers. There is a mean reaction time in prime situation of 760 ms, and a mean reaction time in control situation of 794 ms. This difference of 34 ms is not significant (*p* = 0,173). The results are visualized in graph 3 and 4.



Graph 3: visualisation of high proficient RT



Graph 4: spreading of reaction times

DISCUSSION

The present study tries explores the functioning of the mental lexicon for the multilingual brain. We have introduced three models: the independent model, the revised hierarchical model and the BIA+ model. We expected to find results that would support the revised hierarchical model, according to our hypothesis. This would mean that we would have found a faster reaction time in prime situation for the high proficient group, and no effect of priming for the low proficient group.

The BIA+ model predicts that we would find a faster RT for both of the proficiency groups. This faster RT is caused by shared lexical and conceptual representations, causing the activation of related concepts to the prime word and thus making the reaction time of the target faster.

The revised hierarchical model on the other hand predicts that we would find a faster reaction time for the high proficient group, because the participants are predicted to access the conceptual representations directly from L2 input and thus activate related concepts to L2 input. Low proficient speakers, however, cannot access conceptual representations via L2 input and have to access the L1 translation equivalents first. This means we don't expect to find faster RTs for low proficient speakers.

Lastly, according to the independent model, we expect to find no influence of semantic priming in any of the circumstances. This is because the model describes two different mental lexicons for the languages of the speaker that do not interact.

Our results support the independent model of Kolers (1963). The results as describes above do not show any influence of semantic priming on the reaction time. This would mean that a speaker has a different mental lexicon for every language that he speaks and that the different systems do not interact.

In its current form, our results do not support our hypothesis. There are some factors that possibly have contributed to this outcome. Firstly, and most importantly, the difference in proficiency between the two groups was rather small. There were participants in the low proficient group with a LexTALE score of 59%, and participants in the high proficient group with a LexTALE score of 61%. This minimal difference in proficiency may not have been enough to make a clear distinction between the speakers and even less to cause a difference in mental systems. If this study was to redo, we recommend to find participants with a larger difference in proficiency. The number of 20 participants is also to be increased.

A second factor that has potentially influenced our results is the priming direction. Backward priming is known to be a weaker form of priming that has not been studied in this context before. We chose this direction of priming to be able to distinguish the revised hierarchical model and the BIA+ model, but we have to keep in mind that the backward priming has potentially influenced the outcome.

CONCLUSION

In this study, we have tried to determine the organisation of the lexical system of a bilingual speaker. We did this with the help of three models: the revised hierarchical model, the BIA+ model and the independent model. To answer our research question 'How is the system of lexical processing organised in the multilingual brain?', we performed a cross-language semantic priming experiment with 20 Dutch French bilinguals. In the experiment, they had to name 50 images in Dutch, after they had seen a (semantically related or not) prime word. The group has been divided in two levels of proficiency according to their LexTALE scores. Our results show no significant difference in reaction times for the two different conditions, even though the reaction time for the group of high proficient speakers are slightly faster, but this is not significant. The results in their current form support the independent model in which there are separate semantic lexica for every language of a speaker. Our hypothesis was that the results would support the revised hierarchical model, we stated a couple of factors that might have influenced the results, namely the small difference in proficiency level between the two groups, the small number of participants and the priming direction.

ROLE OF THE STUDENT

The student suggested the subject of this study herself because of her great interest in second language acquisition and bilingualism. The general idea was presented to her supervisors Jenny Doetjes and Sarah von Grebmer zu Wolfsthurn who helped to concretize the research. The implementation of the experimental design in E-prime done with some help of Sarah, who also helped with the data analysis. Processing the results and the writing were done by the student.

REFERENCES

1. Brysbaert, M. Duyck, W. Is it time to leave behind the Revised Hierarchical Model of bilingual language processing after fifteen years of service? In: *Bilingualism: Language and Cognition 13* (2010), 359 – 371.
2. Collins, A.M. Loftus, E.F. A Spreading-Activation Theory of Semantic Processing. In: *Psychological Review 82* (1975), 407 – 428.
3. Dijkstra, T. Van Heuven, Walter J B. The Architecture of the Bilingual Word Recognition System: from Identification to Decision. In: *Bilingualism: Language and Cognition 5* (2002) 175 – 197.
4. Farahian, Majid. Mental Lexicon: Its Organization and Representation. In: *BRAIN Broad Research in Artificial Intelligence and Neuroscience 2* (2011), 56 – 59.
5. Hutchison, K.A. Neely, J.H. Johnson, J.D. With Great Expectations, Can Two 'Wrongs' Prime a 'Right'? In: *Journal of Experimental*

Psychology 27 (2001), 1451- 1436.
6. Kolers, P.A. Interlingual Word Associations. In: *Journal of Verbal Learning and Verbal Behaviour*, 2 (1963) 291 – 300.
7. Kroll, J.F. Steward, E. Category Interference in Translation and Picture Naming: Evidence for asymmetric

representations. In: *Journal of Memory and Languages*, 35 (2002), 648 – 665.
8. McNamara, T.P. *Semantic Priming: Perspectives from Memory and Word Recognition*. New York and Hove: Psychology Press. 2005.

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connections between bilingual memory