Inducing asymmetrical switch costs in bilingual language comprehension by language practice.

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Abstract

The most widely discussed observation in the language control literature is the larger cost found when switching into the first than the second language (i.e., asymmetrical switch costs), which has been determined as a marker of persisting, reactive inhibition. While this is a common effect in bilingual language production, it generally does not occur in bilingual language comprehension. In this bilingual language comprehension study, we manipulated the relative activation of languages by letting participants practice in pure language blocks prior to a mixed language block. While no effect was found of practicing second-language words, asymmetrical switch costs were observed when practicing the same (Experiments 1 and 2) or different first-language words (Experiment 3) as in the following mixed language block. These findings indicate that, similar to bilingual production, bilingual comprehension relies on persisting, reactive language control.

Words: 136

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According to several bilingual production models, language control, which is the process that makes sure that the target language is being processed and not the non-target language, is a persisting, reactive inhibitory process (e.g., Declerck, Koch, & Philipp, 2015; Green, 1998; Schwieter & Sunderman, 2008). Reactive inhibition means that a higher activation level of the non-target language will result in this language being suppressed to a higher degree. Persisting inhibition means that the inhibitory process will continue into the succeeding word(s). Whereas there is evidence for persisting, reactive inhibition during bilingual language production (e.g., asymmetrical switch costs), there is little evidence for such a process during bilingual language comprehension. This is puzzling, since there are models that postulate that production-based and comprehension-based language control rely on the same processes. Hence, in the current study we set out to investigate whether bilingual language comprehension relies on persisting, reactive inhibition by increasing the activation of a language through prior language practice and examining its effect on asymmetrical switch costs.

Asymmetrical switch costs are a measure found with the language switching task (for a review, see Declerck & Philipp, 2015). In this task bilinguals typically have to either name digits or pictures in one of two languages based on a language cue (production-based language switching; e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999) or categorize written words of two languages (comprehension-based language switching; e.g., Grainger & Beauvillain, 1987; Thomas & Allport, 2000). A typical finding in both production-based (e.g., Fink & Goldrick, 2015; Meuter & Allport, 1999) and comprehension-based language switching (e.g., Orfinadou & Sumner, 2005; Thomas & Allport, 2000) is that performance is worse when the language of the current trial is different from that in the prior trial (switch trial) than when the same language was used in the current as in the prior trial (repetition trial), an effect typically referred to as switch costs.

Moreover, switch costs can be larger for the first language (L1) than for the second language (L2) during bilingual language production (e.g., Meuter & Allport, 1999; Peeters, Runnqvist, Bertrand, & Grainger, 2014; for reviews see, Bobb & Wodniecka, 2013; Declerck & Philipp, 2015). These asymmetrical switch costs have typically been explained with persisting, reactive inhibition between languages (Green, 1998; Meuter & Allport, 1999; for a persisting, reactive activation account, see Philipp, Gade, & Koch, 2007)[1]: while processing the target language on trial n-1, the non-target language will be inhibited. This inhibition is assumed to persist into the next trial (i.e., trial n). Hence, when the non-target language of trial n-1 becomes the target language of trial n (switch trial), the inhibition that was implemented on trial n-1 will persist into trial n. In turn, this persisting inhibition has to be overcome in order to select the word. No persisting inhibition has to be overcome when the same target language is used on trial n-1 and trial n (repetition trial), making it harder to switch between languages than repeat the same language across trials due to persisting inhibition.

Reactive inhibition entails that a higher amount of activation will result in more inhibition of the non-target language. This can explain asymmetrical switch costs, since bilinguals typically have a higher activation for their L1 than their L2 due to more experience with L1. Hence, more inhibition on L1 is required during L2 production than L2 inhibition during L1 production. In turn, due to persisting inhibition, it will be more difficult to switch to L1 after previously having produced in L2 than switching to L2 after having produced in L1.

Whereas asymmetrical switch costs are generally observed in language switching studies that investigated bilingual language production (e.g., Declerck et al., 2015; Meuter & Allport, 1999; Philipp et al., 2007; Verhoef, Roelofs, & Chwilla, 2009; however, see e.g., Christoffels, Firk, & Schiller, 2007; Declerck, Koch, & Philipp, 2012; Gollan & Ferreira, 2009), typically no such asymmetrical switch costs are observed in bilingual language comprehension studies, such as studies that used a semantic categorization task (Macizo, Bajo, & Paolieri, 2012), a number categorization task (Hirsch, Declerck, & Koch, 2015; however, see Jackson, Swainson, Mullin, Cunnington, & Jackson, 2004), a lexical decision task (Aparicio & Lavaur, 2014; Orfinadou & Sumner, 2005; Thomas & Allport, 2000; Von Studnitz & Green, 1997), a picture-sentence matching task (Philipp & Huestegge, 2015), and with a visual world paradigm (Olson, 2016). In these bilingual language comprehension studies, the pattern generally shows similar L1 and L2 switch costs. This begs the question whether there is persisting, reactive inhibition during bilingual language comprehension.

According to several models, bilingual language comprehension should rely on persisting, reactive inhibition if bilingual language production does, since they assume similar control processes in both modalities (however, see Blanco-Elorrieta & Pylkkänen, 2016). The BIA-d model (Grainger, Midgely, & Holcomb, 2010), for example, proposes that both production-based and comprehension-based language control rely on the same inhibitory processes governed by language nodes (Grainger & Dijkstra, 1992; van Heuven, Dijkstra, & Grainger, 1998) that determine the relative activation levels of word representations in each language. The BIA+ (Dijkstra & van Heuven, 2002), also assumes that production-based and comprehension-based language control rely on similar language control processes, since they proposed that comprehension-based language control occurs between task schemas, similar to those proposed in bilingual language production models (cf. Green, 1998; Schwieter & Sunderman, 2008). Finally, several results obtained in bilingual language comprehension studies (e.g., Thomas & Allport, 2000; Von Studnitz & Green, 2002) have been explained with production-based language control models.

In the current study we set out to investigate whether comprehension-based language control persists and is reactive by implementing pure language blocks prior to the mixed language block. During these pure language blocks, activation of the practiced language would be increased and the language that was not practiced would be inhibited (Declerck & Philipp, 2017; Van Assche, Duyck, & Gollan, 2013). Hence, practicing a language should result in a relatively higher activation of that language in comparison to the language that was not practiced. In turn, if bilingual language comprehension relies on persisting, reactive language control, we should find larger switch costs for the practiced language than for the language that was not practiced, since the higher amount of activation for the practiced language should result in more inhibition for that language, which then persists into the next trial, and thus should be harder to overcome.

Experiment 1

In Experiment 1, we investigated whether asymmetrical switch costs could be affected by prior language practice. To this end, we let participants first practice a size categorization task with eight written French words in pure language blocks. Afterwards, a size categorization task with the same eight written French words and their English translation had to be performed in a mixed language block. In line with the idea of persisting, reactive inhibition one would expect larger French switch costs than English switch costs, due to the French practice which should have increased the activation of French and the specific French words.

Method

Participants. 16 French-speaking participants took part that spoke English as their second language (8 male, mean age = 23.9). Prior to the experiment, the participants filled in a questionnaire about their French and English proficiency and completed a French (Brysbaert, 2013) and English (Lemhöfer & Broersma, 2012) vocabulary test. The questionnaire consisted out of questions about their age-of-acquisition, the average percentage of language use during childhood and current language use, and the bilinguals had to rate their level of spoken, written, and reading skills in French and English on a 7-point scale, with one being very bad and seven being very good (see Table 1).

--Table 1--

Material and task. Participants had to classify eight written French words and their translation equivalent English words, none of which were cognates or contained diacritics, as larger or smaller than one meter (for an overview of the written words in French and English, see Appendix). The participants indicated their size classification by pressing the key “j” or “f” on a keyboard (the mapping of the response keys to the two sizes [i.e., smaller or larger than one meter] was counterbalanced across participants).

Procedure. Prior to the experiment, the instructions were presented in French (L1) both orally and visually, with an emphasis on speed and accuracy. Following the instructions, the participants performed seven pure French blocks of 80 trials each, after which they had to perform one mixed language block of 80 trials. The mixed language block contained the same written French words as those used in the pure French blocks, and their English translation equivalent.

In the pure French blocks, each of the eight words was presented ten times, whereas in the mixed language blocks, each of the sixteen words was presented five times. The same word or its translation equivalent never followed each other. Moreover, in the mixed language blocks an equal amount of French and English trials were presented, both of which consisted out of 50% switch trials and 50% repetition trials.

Each trial started with a written word presented in the center of the screen, which stayed visible until a response was recorded. After the participant´s response there was a 200 ms interval until the next written word would be presented.

Analysis. The first trial of each block, error trials, and trials following an error trial were excluded from reaction time (RT) analyses. Furthermore, RTs that were larger or smaller than two standard deviations from the mean (per participant) were discarded as outliers. Taking these criteria into account resulted in the exclusion of 13.3% of the data.

All data analyses were run with the lme4 package (Bates, Maechler, Bolker, & Walker, 2014) in the statistical software R (RdevelopmentCoreTeam, 2008), and *t*- and *z*-values were used to determine statistical significance. More specifically, *t*- and *z*-values larger or equal to 1.96 were deemed significant (Baayen, 2008). The RT data were analyzed using mixed-effects models (Baayen, Davidson, & Bates, 2008). The error data were analyzed using a logistic mixed model (Jaeger, 2008). However, we focused on the RTs since none of the effects reached significance in the error analyses. This goes for all three experiments (all *z*s < 1.96; see Table 3 for the error means).

The factors consisted of language (French vs. English) and transition (switch vs. repetition trials). Both participants and items were considered random factors, with all fixed effects varying by all random factors (Barr, Levy, Scheepers, & Tily, 2013)[2].

Results and Discussion

As can be seen in Table 2, the RT data revealed a significant main effect of language, with slower performance in English trials (896 ms) than in French trials (859 ms; see Table 3), and of transition, with switch trials (891 ms) being slower than repetition trials (863 ms). The interaction was also significant, with smaller English switch costs (switch: 864 ms vs. repetition: 929 ms; *b* =

59.42, t = 1.38) than French switch costs (switch: 919 ms vs. repetition: 804 ms; b = 114.48, t = 2.48).

--Table 2--

--Table 3--

We additionally wanted to examine whether the switch cost asymmetry observed above was due to the pure language blocks preceding the mixed language blocks. Hence, we ran a control experiment with 16 new French-English bilinguals, which was methodologically exactly the same experiment as Experiment 1, but without the pure language blocks preceding the mixed block. The results showed no difference between L1 and L2 switch costs in both RT, b = 10.82, t = 0.19 (French switch costs: -2 ms; English switch costs: -26 ms), and error rates, b = 1.32, z = 1.32 (French switch costs: -1%; English switch costs: 2.7%), which indicates that the pure language blocks did instigate the switch cost asymmetry in the experiment above. However, we also did not observe any switch costs in either RT, b = 4.11, t = 0.10, or error rates, b = 0.49, z = 0.46. We felt that this made the non-significant interaction between language and transition less informative. Thus, we further investigated the influence of prior pure language blocks on mixed language blocks in Experiment 2.

Taken together, we observed asymmetrical switch costs (L1 switch costs > L2 switch costs) with a semantic categorization task by letting French-English bilinguals practice French (L1) words prior to the mixed language block. These results show that asymmetrical switch costs can be obtained during bilingual language comprehension. This is in contrast with prior language switching studies that used semantic categorization tasks without prior pure language block, where no asymmetrical switch costs were observed (Macizo et al., 2012).

Experiment 2

In Experiment 1, we found evidence for larger L1 than L2 switch costs during bilingual language comprehension by letting bilinguals practice their L1 prior to a mixed language block. To further establish this effect, we had other French-English bilinguals perform a similar experiment with a different categorization task (categorization of words referring to animals or not). Most importantly, half of the participants practiced in pure French blocks, whereas the other half in pure English blocks. Here we wanted to investigate whether we could replicate the pattern observed in Experiment 1 when French words were practiced, and whether a reversed asymmetrical or symmetrical switch costs pattern could be found when English words were practiced, since this would indicate that the asymmetrical switch costs were due to practicing the words in French prior to the mixed language blocks.

Method

Participants. 32 new French-speaking participants took part that spoke English as their second language (16 male, mean age = 21.2). Prior to the experiment, the participants filled in the same questionnaire and vocabulary tests as in Experiment 1 (see Table 1).

Material, Task, and Procedure. The material, task, and procedure of Experiment 2 were similar to those used in Experiment 1. One difference was that sixteen different written French words and their English translation equivalent were used (for an overview of the written words in French and English, see Appendix), since only a small amount of stimuli were used in Experiment 1. Half of the participants got one set of eight written French words and their English translation equivalent, while the other half got the other set of eight written French words and their English translation equivalent. Importantly, for half of the participants the words in the pure language blocks were presented in French, whereas for the other half they were presented in English.

Finally, another task was used: The participants had to indicate whether each written word was an animal or not by pressing the key “j” or “f” on a keyboard (the mapping of the response keys to the semantic categories [i.e., animal or not] was counterbalanced across participants).

The same exclusion criteria were used as in Experiment 1, which resulted in the exclusion of 14.5% of the data.

Analysis. The only difference in analysis from Experiment 1 was that the factors consisted of language (French vs. English), transition (switch vs. repetition trials), and practice (French practice vs. English practice).

Results and Discussion

As can be seen in Table 2, the RT data revealed a significant main effect of language, with slower responses in English (683 ms) than in French (657 ms; see Table 3). The interaction between language and transition was also significant, with smaller English switch costs (switch: 679 ms vs. repetition: 685 ms; $b = 8.96$, $t = 0.69$) than French switch costs (switch: 669 ms vs. repetition: 641 ms; $b = 22.74$, $t = 1.61$), as was the interaction between language and practice, with a smaller language difference when participants practiced in English (French: 633 ms vs. English: 645 ms) than when they practiced in French (French: 676 ms vs. English: 722 ms). Importantly, also the three-way interaction was significant (see Figure 2), with symmetrical switch costs when participants practiced in English (French switch costs: 20 ms vs. English switch costs: 19 ms; $b = 4.38$, $t = 0.17$) and asymmetrical switch costs when participants practiced in French (French switch costs: 36 ms vs. English switch costs: -33 ms; $b = 71.71$, $t = 2.32$).

Taken together, we found the same asymmetrical switch cost pattern as in Experiment 1 when French was practiced. When English was practiced prior to the mixed language block, on the other hand, symmetrical switch costs were observed. This provides evidence that the asymmetry effect found when practicing French was due to language practice, otherwise we should have observed a similar asymmetrical switch cost pattern for participants that practiced French and those that practiced English prior to the mixed language block.

Furthermore, not finding reversed asymmetrical switch costs (L2 switch costs > L1 switch costs) due to English (L2) practice is along the lines of what previous studies found that investigated the effect of language practice in different languages (e.g., Van Assche et al., 2013; Misra, Guo, Bobb, & Kroll, 2012). Van Assche et al. (2013), for example, let bilinguals first perform a fluency task in a specific language, after which they had to perform a fluency task in another language. Whereas their results also showed that languages were differently influenced, they found that the least dominant language (English in our case) was not affected by prior practice in the more dominant language, whereas the more dominant language was affected by prior practice in the least dominant language. In our study, only practice in the dominant language had an effect. This difference with prior studies could be due to the use of mixed language blocks in the current study, whereas Van Assche et al. (2013) used pure language blocks. More specifically, different language control processes are implemented during mixed language blocks than during pure language blocks (e.g., Declerck, Philipp, & Koch, 2013; Ma, Li, & Guo, 2016). Hence, it could be that the language practice differently affected the control processes in mixed and pure language blocks.

Experiment 3

In Experiments 1 and 2, we found evidence for asymmetrical switch costs during bilingual language comprehension. However, this was found by practicing a set of eight written words in a specific language that were later tested in a mixed language block. Hence, not just the language was practiced, and thus received additional activation, but also the set of words were practiced, and thus the word representations received additional activation. In the current experiment we examined whether a similar pattern would be obtained when using a different set of words in pure language blocks and mixed language block, since this would only allow language practice and thus increase language activation, without any word practice and thus no increased activation of specific word representations.

Method

Participants. 16 new French-speaking participants took part that spoke English as their second language (3 male, mean age = 21.8). Prior to the experiment, the participants filled in the same questionnaire and vocabulary tests as in Experiment 1 (see Table 1).

Material, Task, Procedure, and Analysis. The material, task, and procedure of Experiment 3 were identical to those used in Experiment 2. The main difference was that the written words (or their English translation equivalents) that were used in the pure French blocks, since no pure English blocks were used, were not used in the mixed language blocks. In turn, words of the other set of written words were used in the pure French blocks and the mixed language block (i.e., two sets of written words were used across participants in Experiment 2). The implementation of the two sets of written words in the pure language blocks and the mixed language block was counterbalanced across participants.

The design was identical to Experiment 1, with two factors: language (French vs. English) and transition (switch vs. repetition trials). The same exclusion criteria were used as in Experiment 1, which resulted in the exclusion of 16.5% of the data.

Results and Discussion

As can be seen in Table 2, the RT data revealed a significant main effect of language, with slower responses in English trials (824 ms) than in French trials (789 ms; see Table 3), and a significant main effect of language transition, with slower responses in switch trials (828 ms) than in repetition trials (777 ms). The interaction between language and language transition was also significant (see Figure 3), with smaller English switch costs (switch: 812 ms vs. repetition: 837 ms; b = 33.19, t = 0.82) than French switch costs (switch: 844 ms vs. repetition: 725 ms; b = 113.38, t = 2.63).

We were also interested in whether this asymmetry obtained by practicing French would differ from when not only the language but also the specific words were practiced. Hence, we compared the results obtained in Experiment 3 with the results from Experiment 2 (restricted to those participants that practiced in French). This comparison showed no significant difference in asymmetrical switch costs between practicing a language (Experiment 3) and practicing a language/language-specific words (Experiment 2), b = 79.44, t = 1.09.

Taken together, asymmetrical switch costs can also be found when solely practicing a language. Moreover, this pattern is similar to that found when the language and words are practiced.

General Discussion

In the present study we examined whether comprehension-based language control persists and is reactive. To this end, we implemented pure language blocks prior to a mixed language block, so that bilinguals would practice a specific language. The results showed larger French (L1) than English (L2) switch costs when French-English bilinguals practiced the same (Experiments 1 and 2) or different French words (Experiment 3) in the pure language blocks and the mixed language block. When English words were practiced, on the other hand, no difference in switch costs across languages was observed (Experiment 2).

Unlike most prior studies, these data show that asymmetrical switch costs can be observed during bilingual language comprehension, when a language is practiced beforehand. Explicit evidence for the effect of prior language blocks on asymmetrical switch costs was observed in Experiment 2, where asymmetrical switch costs were found when French was practiced prior to the mixed language blocks, but not when English was practiced. If the pure language blocks had no effect, we should have observed a similar switch cost pattern across languages when French and English was practiced prior to the mixed language blocks.

The observation of asymmetrical switch costs due to prior pure language blocks suggests that in most prior bilingual language comprehension studies where no prior language practice took place, the difference in language activation was not large enough to elicit asymmetrical switch costs. For example, the study of Macizo et al. (2012) also investigated language switching with a semantic categorization task, similar to the current study, but without any language practice prior to the mixed language blocks. In Macizo et al. (2012), as with most bilingual comprehension studies, no asymmetrical switch costs were observed. This does not mean that there was no difference in activation between languages in prior language switching studies that investigated bilingual language comprehension, since significant overall language effects were observed in some of those studies (e.g., Hirsch et al., 2015; Thomas & Allport, 2000). However, it might be that the difference between the languages was not large enough in those studies to elicit asymmetrical switch costs across languages.

The larger switch costs for the practiced language indicate that comprehension-based language control relies on persisting, reactive inhibition (cf. Meuter & Allport, 1998): practicing a language prior to the mixed language block should lead to an increase in activation of the practice language in the mixed language block, relative to the language that was not practiced (Declerck &

Philipp, 2017; Van Assche et al., 2013). This should have resulted in more inhibition being used in the mixed language block on the practiced language than on the language that was not practiced. In turn, the increased amount of inhibition should have persisted into the next trial making it more difficult to produce in the practiced language.

Persisting, reactive inhibition could also explain why no significant English switch costs were found when French was practiced. This pattern could have been observed because of the relatively smaller activation of English words, due to practicing French prior to the mixed language block, requiring little inhibition for English when on trial n-1 French was being processed. In turn, there was little inhibition to overcome when on trial n an English word was presented (i.e., switch trial; Green, 1998).

Finally, finding asymmetrical switch costs in a bilingual language comprehension study, similar to the pattern observed in bilingual language production studies, indicates that language control during comprehension and production might not be that different. More specifically, it points toward a similar mechanism of language control that underlies both comprehension- and production-based language control, namely persisting, reactive inhibition. This is in line with the BIA-d and BIA+, since they both assume that comprehension-based and production-based language control rely on similar processes. The BIA-d, for example, assumes that both bilingual comprehension and production rely on the same language control process that operates via language nodes. These language nodes are activated by word representations during bilingual language comprehension. During bilingual language production, on the other hand, the language nodes become activated by the goal to speak a language. This difference in how the language nodes are activated could explain why asymmetrical switch costs are observed in production, but not in comprehension without prior language practice: the goal to speak a language could activate the corresponding language node to a higher degree than the activation that comes from the language of the word that is being comprehended.

In the current study, we circumvented this issue during bilingual language comprehension by increasing the activation of a specific language node by practicing a language prior to the mixed language block. Consequently, asymmetrical switch costs should be found, which was the case in the current study.

In sum, asymmetrical switch costs can be observed during bilingual language comprehension by practicing L1 prior to the mixed language blocks. This shows that, similar to bilingual language production, persisting, reactive language control is implemented during bilingual language comprehension.

Footnotes

[1] Other interpretations for asymmetrical switch costs have been proposed (Finkbeiner, Almeida, Janssen, & Caramazza, 2006; Verhoef et al., 2009). However, there is little evidence for these explanations (for reviews, see Bobb & Wodniecka, 2013; Declerck & Philipp, 2015).

[2] Some convergence issues arose with the analysis, which were resolved by not allowing the factors to vary by items. When comparing the fit of our reduced model (AIC: 16510) with a full random effects model (AIC: 16525), we found that there was no difference between the two (p = .970). Thus, the observed effects were not due to variability that was not captured by the model (cf. Declerck, Lemhöfer, & Grainger, 2016; Slevc, Davey, & Linck, 2016). The same goes for Experiment 2 (reduced model AIC = 15406; full random effects model AIC = 15421; difference: p = 0.968), and Experiment 3 (reduced model AIC = 29082; full random effects model AIC = 29182; difference: p = 0.999) where additionally the interactions did not vary by participants in the reduced model.

Authors' Note

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Table 1. Overview of the demographic information for Experiments 1-3. The information consists of the average age-of-acquisition of both languages and the average percentage of time the participants spoke either language during childhood and currently. Furthermore, the average self-rated scores for speaking, writing and reading both languages is given, as is the average LexTALE scores for both languages.

	Experiment 1		Experiment 2		Experiment 3	
Effects	French	English	French	English	French	English
Age-of-acquisition	0.3	9.4	0.6	8.5	0.9	8.7
% used during childhood	87.5	12.5	85.0	15.0	80.6	19.4
% currently used	75.6	24.4	80.0	20.0	68.7	31.3
Spoken	6.3	4.1	6.5	4.4	6.3	4.1
Written	6.0	4.1	6.3	4.5	5.9	4.0
Reading	6.8	4.6	6.5	5.0	6.3	4.1
LexTALE	91.6	68.9	90.4	71.5	89.3	72.3

Table 2. *b*-, and *t*-values, of Experiments 1-3 for RT with variables: language (French vs. English), transition (switch vs. repetition trials), and for Experiment 2 also the variable practice (French practice vs. English practice).

	Experiment 1		Experiment 2		Experiment 3	
Effects	*b*	*t*	*b*	*t*	*b*	*t*
Intercept	790.79	13.04*	664.99	18.93*	724.55	22.34*
Language	123.94	2.32*	75.43	3.92*	117.67	2.30*
Transition	120.12	3.08*	31.94	1.88	113.13	2.87*
Practice			40.40	0.89		
Language x Transition	179.74	3.13*	64.98	2.77*	146.78	2.47*
Language x Practice			67.89	2.94*		
Transition x Practice			20.63	0.86		
Language x Transition x Practice			68.33	2.09*		

* significant effect

Table 3. Overall RT in ms and percentage of errors (PE) of Experiments 1-3, as a function of language (French vs. English), transition (switch vs. repetition trials), and for Experiment 2 there was also the factor practice (French practice vs. English practice).

		Experiment 1		Experiment 2				Experiment 3	
				French practice		English practice			
		French	English	French	English	French	English	French	English
RT	Switch	919	864	695	704	643	654	844	812
	Repetition	804	929	659	737	623	635	725	837
PE	Switch	7.5	16.3	5.6	15.6	8.8	7.5	10	16.3
	Repetition	6.3	10.6	6.9	15.6	10.6	13.8	7.5	16.9

Appendix.

French and English words used in Experiments 1-3.

French words	English words
Experiment 1	
aiguille	needle
avion	airplane
camion	truck
doigt	finger
lune	moon
souris	mouse
tasse	cup
vache	cow
Experiment 2 and 3 – set a	
cerf	deer
cheval	horse
jupe	skirt
lapin	rabbit
maison	house
porte	door
souris	mouse
stylo	pen
Experiment 2 and 3 – set b	
arbre	tree
fourmi	ant
gant	glove
livre	book
mur	wall
oiseau	bird
ours	bear
vache	cow