Lexical Access in Spanish-English Bilinguals : Manual Stroop Effect

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Abstract. The Stroop task is a popular paradigm to investigate bilingual cognitive control. The present study, with Spanish-English bilinguals, investigates the degree of automaticity in bilingual language processing and observes the role that proficiency plays in it. With L1 and L2, there is an interference effect in Control and Incongruent condition, and participants always respond faster in a Control condition. Moreover, participants' performance of using L1 is not better than L2, which is due to the high level of proficiency of participants in L2. Whether the experience of language influence responses, it cannot be concluded through experiments alone. Therefore, language experience cannot affect responses.

1 Introduction

McLeod (1991) stated the Stroop is an extensively used paradigm in various studies. MacLeod and MacDonald (2000) stated that in the classic Stroop effect, naming the colour of an inconsistent colour word (e.g. the word RED printed in green ink; say, 'green') is much slower and has more errors compared to naming the colour of a consistent word(e.g. XXX or CAT printed in green; say 'green'). This is because the automatic process of reading, which generates the competition, interferes with the process of colour naming[4]. Marian and Spivey (2003), through two experiments of eye-tracking, examined Russian-English bilinguals spoken language processing with results supporting existing findings of parallel activation of laxical items within and between languages. However, the results of their experiments show that some magnitude differences in language competition effect between first and second language, which are influenced by various factors, like stimuli, language background, and language mode[5]. Sabourin and Vinerte (2015) have also stated, bilinguals with two language systems, through using cognitive control skills must pay attention to the linguistic environment, select the appropriate language, inhibit the appropriate language, and manage conflict between the two languages. Whilst they argued that the experience in managing two languages gives them an advantage in terms of general cognitive control skills[7]. Bialystok, Craik, and Luk (2008) stated that bilinguals display a larger Stroop effect in their L1 opposite to their L2. This happens because the L1, being more automatic, takes less to become activated and thus produces greater interference. Contrastingly, L2 takes longer, thus it does not interfere with the lexical nodes in the L1[2]. However, Paap and Greenberg (2013) did not agree with this notion. Additionally, they compared bilinguals and monolinguals on 19 indicators of executive processing, with several linguistic and non-linguistic tasks and reported that bilinguals have no advantages in executive processing[6].

Although some scholars have questioned bilingual advantages, it is necessary to examine some of the factors that may influence it, like Age of Acquisition (AoA) and task difficulty. As for AoA, Tao, Marzecová, Taft, Asanowicz and Wodniecka (2011) the efficiency of attentional networks was investigated in three groups of the young living in Australia within English monolinguals and early and late Chinese-English bilinguals. The result suggests that factors specific to language experience affect cognitive control mechanisms differently, and that bilinguals had a different set of languages, suggesting the presence of bilingual influences on executive functioning, regardless of the similarity of the two languages. They also assumed that there are relevant early and late bilinguals with more efficient executive networks compared to monolinguals. Whilst there is still differences, namely early bilinguals are better at controlling the two languages, and late bilinguals are better at solve conflict[9].

Regarding bilingual advantage, existing research has focused on the role of context in language processing, including experimental and interactional context. Wu and Thierry (2010) have argued that the effect of language contextual contributed to the theoretical development of bilingual models, and they stated that in the early stages of language processing, lexical candidates are automatically activated in bilinguals who use two languages, even when only one language is available[10]. As the development of research, Wu and Thierry (2013) in their research, Welsh-English bilingual participants performed a non-verbal conflict resolution task, through manipulating the language context and

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presenting words intermittently in Welsh, English, or both languages. The results found that participants' executive ability to resolve interference was enhanced when exposed to a mixed language context compared to a monolingual context, even when irrelevant contextual words were ignored[11]. Simultaneously, a new level of plasticity in bilingual executive control, which depends on a rapidly changing language context instead of years of language experience. The results of this study are like the study of Green and Abutalebi (2013) which addresses Adaptive Control Hypothesis. As for Adaptive Control Hypothesis, they stated that different interactional contexts influence the linguistic demands of the speaker, and these in turn shape the speaker's language control processes, such as during a dual language context, whilst the two languages must be monitored to avoid code-switching as frequently. Likewise, they proposed the suggestion that the context of the interaction (the typical interactional exchange in those context) is important for bilingual speakers to adapt their cognitive control processes and regulate their networks of control[3]. Using the Stroop task Sabourin and Vinerte (2015), examined the effects of Age of Immersion (AoI) about bilingual cognitive control, suggesting that there are no differences between simultaneous and early bilinguals when the task utilises one language. Contrastingly, there are significant differences between them when the task involved mixed languages. In this situation, early bilinguals often display strengthened cognitive abilities, which are associated with bilingualism[7].

In fact, bilingualism is not only associated with a cognitive advantage, but it also connected with the notion of 'bilingual disadvantage', usually linked to bilinguals' vocabulary size.

This experiment partially chose Experiment 2 of Sabourin and Vinerte (2015)[7], but neutral words were excluded instead of using non-lexical strings (e.g., strings of Xs). And it also chose Experiment 2 of Geukes et al (2015)[12], but training participants on new colour was excluded instead of using a bilingual population. There are the key differences from the original experiments including:

1. This study only uses 3 colours because it is more convenient to collect the data online, using a variety of laptops/PCs.

2. Making sure all bilinguals know the same two languages so that the words are known for your sample of bilinguals.

3. There is only one control condition, and this is a non-lexical one (string of Xs). The study therefore needs to compare this control condition with the congruent condition (facilitation effect) and the incongruent condition(interference effect).

By using the Stroop task in Gorilla, chosen Spanish-English bilinguals (as mentioned in the participants' part), measuring the degree of automaticity in bilingual language processing, which is reading not relevant for the task, as well as observing the role that proficiency plays in it. the following questions will be addressed:

1. Whether participants have fewer errors in the Congruent Condition than the Control Condition in their L1 and their L2?

2. Whether participants perform better in the Control Condition than the Incongruent Condition in their L1 and their L2?

3. Whether there is the facilitation effect or the interference effect in L1 and L2?

2 Method

2.1 Participants

There are twenty Spanish-English bilinguals between the age of 28 and 57 (M = 36.0) participating in this experiment. Participants were recruited through the course of linguistics at Lancaster University. Sabourin, L. and members of the ERPLing Laboratory (2009), divided participants into 2 groups, including simultaneous and early. The simultaneous group, AoI is of 0 years of age, namely someone immersed in two languages from birth. The early group, AoI is between one and six years, namely someone immersed in L2 environment at a young age. However, the average of AoI of participants in this experiment is 7.8 years old, over the AoI of the previously mentioned groups. Thus, these participants do not belong to simultaneous or early groups. And these participants are Spanish native speaker, English being their second language. The average age of acquisition of English is 7.8 years old. The average proficiency of Spanish and English is 9.3 and 7.3 respectively. The total data regarding participants is shown in Table 1.

Table 1: Participants

Total	20
Males/Female	11/9
Age	28-57
Average Age	36
Average Age of Acquisition L1	0
Average Age of Acquisition L2	7.8
Average Proficiency of L1	9.3
Average Proficiency of L2	7.3
Exposure	49.65%

2.2 Stimuli

As for stimuli, these were presented to the participants' personal desktop computer and participants used a button box to respond. The stimuli used in the experiment though Gorilla were blue, green, and red, including 'BLUE', 'GREEN', 'VERDE', 'xxX', 'xxX', 'GREEN', 'BLUE', 'GREEN', 'Xxx'.

In this experiment, there are two different sets of experiments, namely Spanish task, English and Spanish task, each with three different types of conditions, which were Control, Congruent and Incongruent. The Control condition is a control item in any colour font, and Congruent condition means the word "red" is used red

font, but Incongruent condition is the word "red" and is green or another colour font. Firstly, in the Spanish task, it consists of Spanish Control, Spanish Congruent and Spanish Incongruent items intermixed. There is also a Mixed Language task, namely all the conditions mentioned above, which appeared intermixed. Secondly, the English and Spanish tasks, which include 25 trials of Control, Congruent and Stroop trials respectively. So, there are a total of 75 trials for each task. Similarly, there is the Mixed Language task, including English and Spanish Control, English and Spanish Congruent and English and Spanish Incongruent trials, that each of items have 25 trials, in total 150 trials. Remarkably, each task has 15 practice trials before the formal experiment. Moreover, these two tasks were counterbalanced for order of presentation, which is like Sabourin and Vinerte's research (2015), shown in Figure 1.

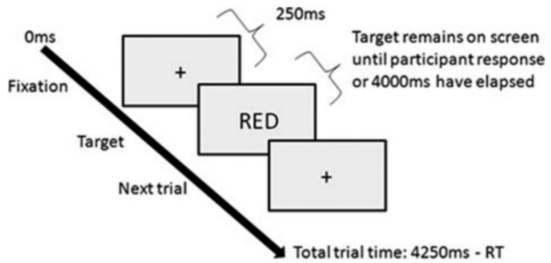


Figure 1: Sample Trial (Sabourin & Vinerte, 2015)

2.3 Procedure

Participants are asked to fill out a consent form and the language background questionnaire. The researcher will ask participants for some basic information, like age, their first and second language, and the proficiency and frequency of using L1 and L2. The experimental description was presented in English, and explains the task, with participants being told that they will see the words in the centre of the screen with some different colour, and will then be asked to press the button that the colour of the words they see on the screen. The experimental operation is specified on the keyboard, with green on the left, red upwards and blue on the right and it is worth noting that participants respond to the colour of the font, not the meaning of the word which is highlighted in the instruction. Moreover, an example will also be presented, such as if the word "green" presents in blue, participants must respond to the colour of "blue" and press the blue button.

Each text starts with a fixation cross in the centre of the screen and lasts for 250 ms. The target is then initiated. Once the target is presented in the screen, it will remain until participants respond or after 4000 ms elapse (like Figure 1). Additionally, these tasks were presented in random order and participants were asked to complete a block of 15 trials to confirm their understanding of the experiment before the formal experiment.

3 Data and discussion

Notably, in the experiment, one participant's data is excluded because there are too many mistakes in the overall experiment. Further, the time reflection of trials exceeding two standard deviations of the average reflection time of the participants' were also excluded. Thus, the following results are obtained.

Table 2: The Data of L1 (Spanish)

Condition	Sum of Correct	Sum of Incorrect	Sum of Total	Accuracy	Error_rate	Ave_RT
Congruent	556	14	570	97.54%	2.46%	849.6170132
Control	553	17	570	97.02%	2.98%	845.1007648
Incongruent	545	25	570	95.61%	4.39%	947.5124031

Table 3: The Data of L2 (English)

Condition	Sum of Correct	Sum of Incorrect	Sum of Total	Accuracy	Error_rate	Ave_RT
Congruent	559	11	570	98.07%	1.93%	849.6170132
Control	553	17	570	97.02%	2.98%	845.1007648
Incongruent	548	22	570	96.14%	3.86%	945.2017308

Table 4: The Total Data of L1 and L2

Condition	Sum of Correct	Sum of Incorrect	Sum of Total	Accuracy	Error_rate	Ave_RT
Congruent	1115	25	1140	97.80%	2.20%	849.6170132
Control	553	17	570	97.02%	2.98%	845.1007648
Incongruent	1093	47	1140	95.88%	4.13%	946.35706695

Regarding the first question, which addresses whether participants perform better within L1 and L2 in the congruent condition, namely less errors than in the control condition, the above results are presented (Table 2 and Table 3). It is clearly shown that the accuracy of the Congruent condition in L1 and L2 is 97.54% and 98.07% respectively. And the accuracy of the Control condition L1 and L2 is 97.02%. Thus, it is concluded that participants have fewer errors in the Congruent condition than in the Control condition, due to the accuracy of the Congruent condition higher than the Control condition.

As for the second question, the rate of error within L1 and L2 in the Control condition is both 2.98%, and the rate of error within L1 and L2 in the Incongruent condition is 4.39% and 3.86%. Therefore, participants in this experiment perform better, with less errors, in the Control condition than the Incongruent condition in L1 and L2. Another question of whether participants perform faster in the Control condition than in the Incongruent condition, essentially addressing whether there is an interference effect in L1 and L2. Interference effect is discussed because in the Incongruent condition, the word "green" is used red or other colour font, such as "GREEN", which disruptive to the participant's response. From Table 3, it is evident that the average reaction time within L1 and L2 in the Control condition and Incongruent condition is 845.1007648 and 946.35706695.Ave_RT(Control)< Ave_RT(Incongruent), it is shown that there is interference effect in L1 and L2 within Incongruent condition, thus participants respond faster in the Control Condition than in the Incongruent Condition.

From the above analysis, it is obvious there is an interference effect in L1 and L2, but this may not be the case in specific situations. Consequently, it must be examined whether the interference effect is bigger in the L1 than the L2.

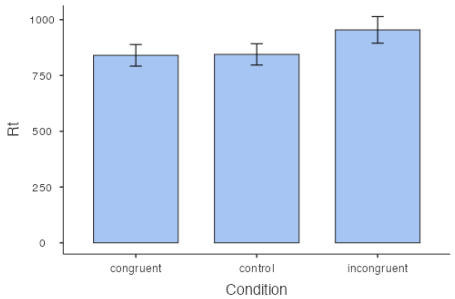
Firstly, in no consideration of language background, we calculated the Mean of RT_Congruent, RT_Control and RT_Incongruent condition. The specific data is shown in Table 5.

Table 5: The Mean of RT_three Conditions

	Rt_congruent	RT_control	Rt_incongruent
N	19	19	19
Missing	0	0	0
Mean	840	844	954
Median	809	816	993
Standard deviation	211	208	260

A Bar Plot was also generated to make the presentation of the data clearer. (Table 6)

Table 6: A Bar Plot of RT three Conditions

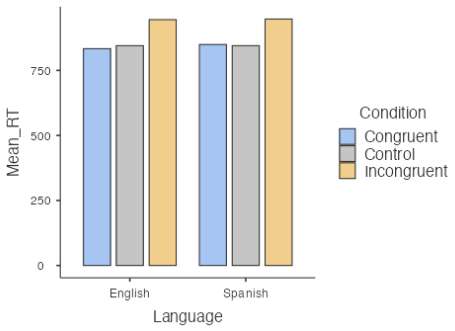


Mean(RT_Congruent)=840ms,Mean(RT_Control)=844ms, the Mean RT of Congruent is less than RT of Control but the results are essentially the same, t(18)=-0.163, P=0.872, which is not remarkable. It is clearly shown that the interference effect is not obvious within Congruent and Control condition, so the language does not influence performance, the result is opposed to the predictions of the study.

However, in Control and Incongruent condition, Mean(RT_Incongruent)=954ms, Mean(RT_Control)=844ms, the Mean RT of Incongruent is longer than RT of Control, t(18)=4.08, P<.001, concluding that the interference effect is significant.

In consideration of the language background, the following data was calculated. The Mean rection time of three conditions is shown in Table 7 with English and Spanish.

Table 7: The Mean_RT of Three Condition in English and Spanish



Concerning Spanish, in Congruent and Control Condition it is t(18)=0.123, p=0.904, and in Incongruent and Control condition is t(18)=3.88, p=0.001. Concerning English, in Congruent and Control condition, t(18)=-0.349, p=0.731, and in Incongruent and Control condition, t(18)=3.37, p=0.003. Since P(the value of Congruent-Control condition)>0.05, P(the value of Incongruent-Control condition)<0.05, the following discuss will only within Incongruent-Control condition.

Table 8: The Data of RT_Spanish in Incongruent-Control Condition

			statistic	df	p	Mean difference
Spanish-Incongruent	Spanish-Control	Student's t	1.07	18.0	0.297	31.2

Table 9: The Data of RT_English in Incongruent-Control Condition

			statistic	df	p	Mean difference
English-Incongruent	English-Control	Student's t	0.904	18.0	0.378	33.3

The Mean of Spanish and English (RT_difference in Incongruent-Control condition) are mostly indifferent, thus there is no notable difference in Spanish and English. Consequently, , the proficiency of the English participants of the L2 experiment is good. Further, Assche, Duyck, and Hartsuiker (2012) stated that bilingual word recognition is language non-selective within the integrated lexicon, with similar word forms within and across languages competing for the spread of selective activation in monolingual contexts and at higher L2 proficiency levels[1]. Compared with monolinguals, bilinguals have more advantages in inhibitory control, so bilinguals are better in suppressing irrelevant information and solving the task in two languages than monolinguals.

4 Conclusion

Conclusively, this essay uses the Stroop task in Gorilla, choosing Spanish-English bilinguals to measure the

degree of automaticity in bilingual language processing and to observe the role that proficiency plays in it. According to the results of experiments, the conclusion is that there is an interference effect in Control and Incongruent condition, and participants respond faster in Control condition regardless of L1 and L2. Ultimately, the language did not influence performance and participants' performance of L1 is not better than L2. Finally, from the analysis, cannot be concluded whether language experience affects responses as there are vast and insignificant differences in the responses between L1 and L2 in the experiment.

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