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TITLE:

Examining Bilingual Language Control Using the Stroop Task

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KEYWORDS:

Stroop task, L1 processing, L2 processing, written word processing, cognitive control, attention, behavioral methods

SUMMARY:

This bilingual Stroop task uses Congruent, Incongruent, and Neutral stimuli presented in blocks in the first language (L1) only, the second language (L2) only, and a combination of L1 and L2. This task allows for an examination of language processing and cognitive control in both L1 and L2.

ABSTRACT:

The Stroop task in its many variations has been used in fields such as psychology, linguistics, and neuroscience to examine questions regarding the automaticity of reading, language processing, and cognitive control, among others. When looking at bilingual individuals, this task can be used to obtain measures of language interference and control in both a bilingual's first language (L1) and second language (L2), as well as for testing the bilingual advantage hypothesis. The Stroop task presents participants with color terms written in congruent colors (e.g., the word RED written in red font), incongruent colors (e.g., the word RED written in green font), in addition to noncolor terms for control (e.g., the word TREE presented in any color), and uses the reaction times from the different conditions to assess the degree of interference and facilitation. In the covert version of the Stroop bilingual task (i.e., participants respond by pressing a button rather than naming aloud), stimuli in the L1 and the L2 are typically presented in separate blocks. While this allows for a simple, yet effective assessment of processing and cognitive control in each language, it fails to capture any potential differences in processing and control within bilingual young adult groups. The present task combines single-language blocks with a novel mixed-language block to increase the level of difficulty of the task, thus making it suitable for testing cognitive control in young adults. Representative results showing differences between

performance in the single-language vs. mixed-language blocks are presented, and the benefits of a mixed-language block are discussed.

INTRODUCTION:

The Stroop task, named after its creator John Ridley Stroop, has enjoyed over 80 years of popularity in the literature[1]. This simple task has been used in hundreds of studies, with different variants created to examine diverse populations and research questions in fields such as psychology, linguistics, and neuroscience. In particular, it has allowed researchers to examine language processes such as the automaticity of written word reading[2], as well as associated cognitive control processes. The latter are also termed "executive control", and encompass a set of processes that include, but are not limited to, inhibition (i.e., interference suppression), attention, conflict monitoring and resolution, selection, and task switching. Looking specifically at bilinguals, the task is highly suitable for obtaining measures of language interference and control in both a bilingual's first language (L1) and second language (L2), as well as for testing the bilingual advantage hypothesis[3], which is currently a topic of considerable debate.[4]

In the original task, the colors red, green, blue, brown, and purple were used in a series of three experiments. In the first experiment, participants read aloud a list of color words printed in incongruent colors (e.g., the word PURPLE printed in blue ink; correct answer "purple") and the same list printed in black ink. In the second experiment, participants said aloud the color of the words in the list (e.g., the word PURPLE printed in blue ink; correct answer "blue") and also named the same colors presented simply as colored squares. Finally, the third experiment examined whether practice of these tasks would affect the outcome, measured in all cases as the time required to read or to name the items in a given list.

The results revealed an interesting asymmetry between word-reading and color-naming: the difference between reading words in different colors and in black was a nonsignificant 2.3 seconds (or a 5.6% increase in the time required to read the color words), while the difference between naming the colors in which incongruent color words were written and naming the colors of squares was a 47.0 seconds, or a significant 74.3% increase in naming time for the words[1]. In other words, colors did not interfere with word reading, but reading strongly interfered with color naming. This increase in color naming time in the presence of a conflicting written word has come to be known as the Stroop effect, and while practice can reduce its magnitude, the interference cannot be altogether eliminated.

Different theories have been proposed to account for the Stroop effect, and in an extensive review of 50 years of Stroop literature, MacLeod[5] describes two of the more predominant ones: 1) the relative speed of processing and 2) selective attention. In the former, words are read faster than colors are named, and this difference in relative processing time causes the Stroop effect. In the latter, the controlled, resource-intensive process of color naming occurs in parallel with the automatic process of reading; the direct competition between diverging word and color information is the source of interference and the Stroop effect[2]. The theory of selective attention is currently the more accepted view[6-9].

Resolving the word-color competition is a cognitively demanding process that requires inhibiting distracting information while turning attention to the goal of the task. In order to correctly name the color, this interference from the automatically processed written word must be suppressed, while attention must be turned to the less practiced, and therefore controlled, task of color naming. Thus, the Stroop task becomes a measure of not only inhibition, but also of attention, and through various manipulations, it allows different levels of cognitive control to be examined[10]. Typically, a decreased magnitude of Stroop interference is considered indicative of better inhibition and attentional resource allocation. A full theoretical review of the Stroop task is beyond the scope of the current paper, but is available from previous works[2,5]. Although nonlinguistic versions of the Stroop task exist (e.g., numerical[11], oculomotor[12], spatial[13]), the current work is interested in linguistic cognitive control, and the remainder of the discussion will therefore be focused on the original linguistic version of the task.

The original Stroop task has undergone various modifications since 1935, and the task commonly used now includes a congruent condition where the color word is presented in the color it names (the word BLUE presented in blue ink; correct answer, "blue") and a control condition that can be made up of colored shapes as in the original task, asterisks (***), a row of symbols such as X's, %'s or #'s, or high-frequency, noncolor-related words (e.g., DOG). These additions allow the Stroop task to examine facilitation effects. Facilitation effects are brought about by the convergence of information from the written word and the visual color in the congruent condition and thereby speed up naming times[7] (although see MacLeod[5] for reliability issues regarding facilitation effects). They can also be used to obtain baseline reading time or color naming time measures using the control items, in addition to Stroop interference effects. Facilitation and interference are defined as the difference in response time between the congruent and control, and as the difference between the incongruent and control trials, respectively, although the Stroop effect can sometimes be calculated as the difference between the congruent and incongruent trial, as in the original task[6]. In the task, the congruent, incongruent, and neutral conditions can be presented in individual blocks (all congruent, all incongruent, or all neutral trials) or in a single block made up of all three conditions, and in a variety of languages.

In the bilingual Stroop task, color terms in the bilingual's first language (L1) or second language (L2), or both, may be presented, and participants may be instructed to name the colors in either of their two languages. This type of task allows researchers to examine both within-language interference (by having the participant name L1 words in the L1 and L2 words in the L2) and between-language interference (naming L1 words in the L2, and vice versa), giving greater insight into how bilinguals process and manage their languages. For example, between-language interference can tell us about lexical representation and the strength of connections between languages in the mental lexicon, and this interference is typically smaller than within-language interference[14].

A variety of language pairs have been used for the Stroop task's bilingual adaptation, including Chinese-English[15,16], Japanese-English[15,17,18], Spanish-English[15,19,20], French-Arabic[21], Arabic-Hebrew[22], English-Greek[14], English-German[14], and Dutch-English[7]. As some have noted[15], factors

such as orthography in these languages can influence the magnitude of the within- and between-language interference. Still, despite differences in magnitude, the Stroop effect is always apparent.

It is important to note that many of the studies that incorporate two languages simultaneously[20] require overt naming, which is susceptible to lexical access effects[23]. In tasks requiring a button press, the L1 and L2 are typically presented separately[24], and only include three or four colors[6,8]. However, such a presentation may make the task too simple for young adults, whose cognitive control abilities are at their peak[25], and result in all participants performing at ceiling. Thus, a single-language presentation with a small number of possible responses may not be sufficient to elicit any possible differences between groups of young adult bilinguals. Therefore, the current protocol seeks to increase the task challenge by increasing the number of color terms and mixing both the L1 and L2 items in a single block, thus not only examining reading automaticity, attention, and cognitive control processes, but also creating a task that is suitable for testing bilingual cognitive control in the young adult population.

In this bilingual task, stimuli were selected in English and French. An example of our stimuli in used is in **Figure 1**. However, any two languages can be used. For this reason, the protocol below will simply use Language A (La) and Language B (Lb) to describe stimuli in each language. For full details of the experimental protocol, please refer to our previous work[26-27].

PROTOCOL:

All methods and procedures described here have been approved by the University of Ottawa Research Ethics Board.

[Place Figure 1 here]

1. Prepare the stimuli for the bilingual Stroop task

NOTE: The Stroop task can be programmed in many commercially available software packages designed for the presentation of behavioral experiments (see **Table of Materials**)

1.1. Create the Congruent items in Language a (La) by programming six color terms written in capital letters in size 60 Times New Roman font, for which the written word and the font color match. For example, present the word GREEN in green font, and the word RED in red font.

1.2. Create the Incongruent items in La by programming six color terms written in capital letters in size 60 Times New Roman font, for which the written word and the font color do not match. For example, present the word GREEN in red font, and the word RED in green font.

1.3. Create the Neutral items in La by programming six noncolor and noncolor-associated terms, written in capital letters in size 60 Times New Roman font. Words are used instead of symbols in order to elicit baseline reading speeds for this reading-based task.

1.3.1. Present each word in each of the colors used in the previous two steps. For example, present the word BOOK in both green and red font.

1.4. Repeat the previous three steps to create items in Language b (Lb). Ensure that you do not use color terms that are cognates in the two languages (e.g., the word BLUE and BLEU in English and French, respectively.)

NOTE: In the current experiment, La was English, and the color terms used were RED, YELLOW, GREEN, BLACK, SILVER, and WHITE. Lb was French, and the color terms used were ROUGE, JAUNE, VERT, NOIR, ARGENT, and BLANC.

2. Create two single-language blocks

2.1. Create an La block which includes 25 Congruent, 25 Incongruent, and 25 Neutral items, for a total of 75 items in the block. Include five Neutral practice items at the beginning of the block.

2.2. Program the experiment to present all items in randomized intermixed trials as shown in **Figure 2**.

[Place Figure 2 here]

2.3. Repeat the previous two steps with 25 Congruent, 25 Incongruent, and 25 Neutral items in Lb, for a total of 75 items in the block.

2.4. Include a self-timed break between the two blocks, and a self-timed break before the presentation of the mixed-language block described in Part 3 below.

3. Create one mixed-language block

3.1. Create a block which includes the 25 Congruent, 25 Incongruent, and 25 Neutral items in La, and the 25 Congruent, 25 Incongruent, and 25 Neutral items in Lb, for a total of 150 items in the block. Include five Neutral practice items at the beginning of the block.

3.2. Program the experiment to present all items in randomized intermixed trials as shown in **Figure 2**.

4. Test participants

4.1. Test participants in a sound-attenuated testing room or booth. Participants should be seated comfortably in front of a computer screen with a button box or keyboard in front of them.

4.2. Explain to the participants that they will see words in different colors on the screen in front of them, and that their task is to press the button that matches the color of the text that they

see. Emphasize that they should answer as quickly and accurately as possible, but that it is okay if they make a mistake. Allow time for participants to ask questions.

4.3. Once participants are comfortable with the task, leave the testing room/booth and allow them to begin the experiment. The experiment will take approximately 8 min to complete.

4.4. At the end of the experiment, thank the participants for their time and debrief them about the task and its purpose.

REPRESENTATIVE RESULTS:

One benefit of including both single-language blocks as well as a mixed-language blocks is that it is possible to confirm the expected results (facilitation and inhibition effects) in each of the participants' languages. It will then be possible to interpret the findings from the mixed-language block. The results presented below are from a study investigating English-French Bilinguals. One of our main research questions focuses on how the age at which a second language is learned (age of acquisition, or AoA) may affect linguistic and general cognitive processing. Thus, here we are using our previously examined AoA groups for illustrative purposes to show different benefits of bilingualism based on AoA. These data include a group of Simultaneous Bilinguals, who acquired both English and French from birth, and a group of Early Bilinguals who acquired English as a first language and were then immersed in French as a second language in an early immersion school program. These participants were exposed to and immersed in French before the age of 7. The participants all reported currently using both English and French on a daily basis and the groups did not differ significantly on proficiency measures.

The first analysis conducted was to examine whether or not each of the participant groups showed the expected facilitation and inhibition effects in each of their languages in the single-language blocks. As can be seen in **Figure 3** below, each of the participant groups showed both facilitation and inhibition effects. However, using only the single-language blocks there was no reason to claim any differences between the Simultaneous and Early Bilinguals. Thus, these two different types of bilinguals are often grouped together for analyses, which may be partly the cause of some of the findings of no cognitive control differences between bilinguals and monolinguals.

[Place Figure 3 here]

However, when we looked at the same effects but in the mixed-language block (**Figure 4**), each language group showed differing effects of facilitation and inhibition. Once the task was made more challenging, between-group differences started to emerge. Different patterns of facilitation and inhibition effects were found, and we can no longer support an argument to collapse across Simultaneous and Early Bilingual participant groups. A mixed-language block likely causes language switching effects, which may result in cognitive costs for some participants. Interestingly, this may allow us to also look specifically at switching costs between La and Lb. However, a discussion of this is beyond the scope of the current paper.

[Place Figure 4 here]

FIGURE LEGENDS:

Figure 1: Stroop task sample stimuli. The color and noncolor terms as well as the background color used in the current experiment are shown. For Incongruent and Neutral stimuli, sample color-word stimuli are shown. In the experiment, any word could be in any of the six colors.

Figure 2: Stroop task procedure. An incongruent trial is shown. Trials began with a 250 ms fixation cross and ended when the participant pressesed a response button or 4,000 ms elapsed.

Figure 3: Results from the single-language blocks. Main effects of congruency (facilitation and inhibition) were seen for each of the participant groups. No significant differences across groups were seen.

Figure 4: Results from the mixed-language blocks. The Simultaneous Bilinguals showed a significant inhibition effect for the English trials while the Early Bilinguals showed a strong facilitation effect for the English trials and a strong inhibition effect for the French trials.

DISCUSSION:

The experimental design presented here describes a twist on the traditional Stroop task. The main goal of this twist is to add a level of complexity to the task that may allow differences to emerge between groups that, due to their age, are being tested at their peak of performance. Essentially, to make the task more challenging in order to be able to distinguish between groups, we added a mixed-language block to the traditional Stroop task, which typically only collects data from trials in one language at a time. For this variant to work, researchers must ensure that critical stimuli do not include cognate items and that control words do not evoke specific colors (e.g., do not use “grass”, due to its association with the color green). One other issue that has not been addressed in the current task is whether any effect of language mode[28] plays a role. We have not currently controlled for the language used by the experimenter with the participant: all participants were tested in English, which was not necessarily the dominant language of all participants. Thus, controlling for language mode is likely to be an important addition in future research. Furthermore, similar to all variants of the linguistic Stroop task, cognitive control is tested through visually-presented language. Therefore, if the task is used to test bilingual cognitive control abilities, it is likely necessary to also employ nonlinguistic tasks of cognitive control. Controlling for language mode and testing nonlinguistic cognition may provide additional comparisons that demonstrate a more realistic pattern of cognitive benefits that result from bilingualism.

As the results indicate, the expected results of facilitation to congruent trials and inhibition to incongruent trials were evident (see **Figure 3**) when we tested participants in a task where only one language was required. No differences were found between the Simultaneous Bilinguals and the Early Bilinguals. This result is consistent with the data found in other Stroop tasks testing a single language at a time[8]. However, it is important to note that these cross-group similarities were no longer seen when a mixed-language task was given in this experiment. This task is likely

more difficult for participants and this increased difficulty caused differences to emerge in the behavioral data. In fact, in another study that used both a single and a mixed-language condition in a non-Stroop conflict resolution task, differences across the conditions were found, with greater executive control functions found during the mixed-language conditions[29].

As we have stated elsewhere[26], the different patterns of facilitation and inhibition found in the mixed-language Stroop task suggest that even though both Simultaneous and Early Bilingual participants acquired both of their languages early, there are likely different underlying processes linked to each language. Importantly, this means that these participants should not be grouped together in tasks testing their language and even more general cognitive skills. Additionally, while these differences found in the mixed-language blocks could be simply due to the added complexity, it is also worth considering the effect of language context. Bilinguals are a very heterogeneous group who use their languages in very different ways, and thus English-French bilinguals in a bilingual city (e.g., Ottawa, Canada) may perform differently from English-French bilinguals from a city with less bilingualism in the languages of the participant (e.g., Toronto, Canada). These context effects (see Green and colleagues[30-31]) will need to be further explored with careful consideration of both past and current usage of both languages for bilingual participants. However, it must be noted that with the behavioral differences that are found, it is not clear what underlying processes cause these cross-group effects. The future directions of this type of research will be to explore what happens at the neurological level by measuring behavioral data concurrently with brain data (e.g., event-related brain potentials).

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DISCLOSURES:

The authors have nothing to disclose.

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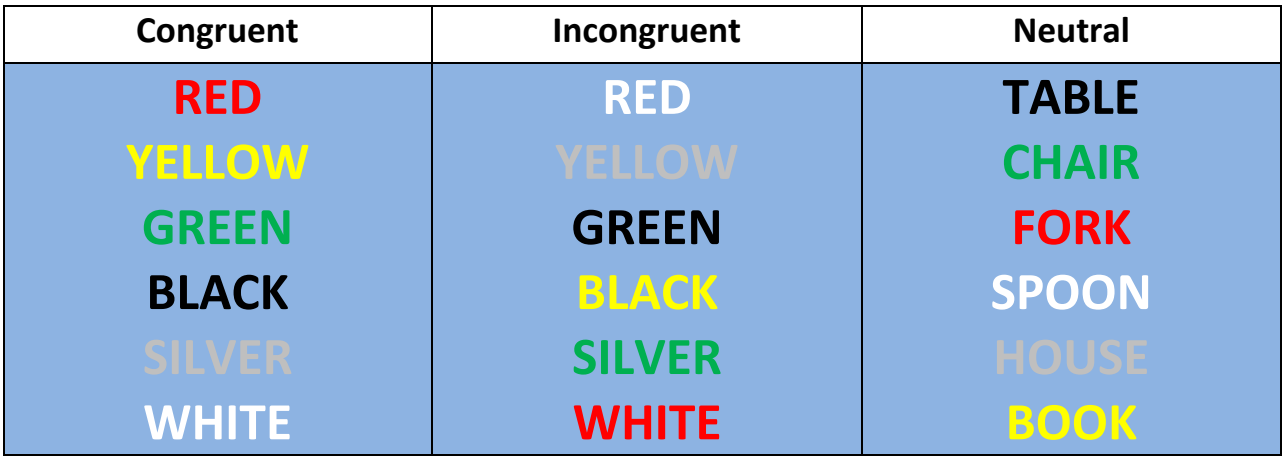
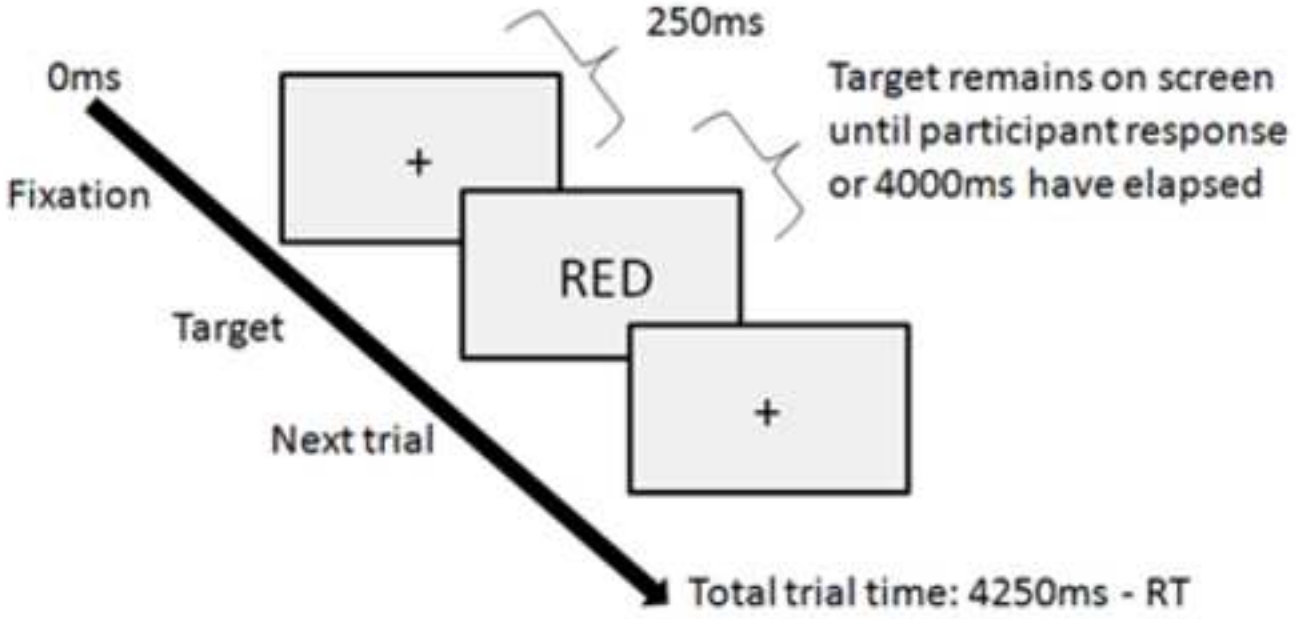
Figure



Figure



Figure

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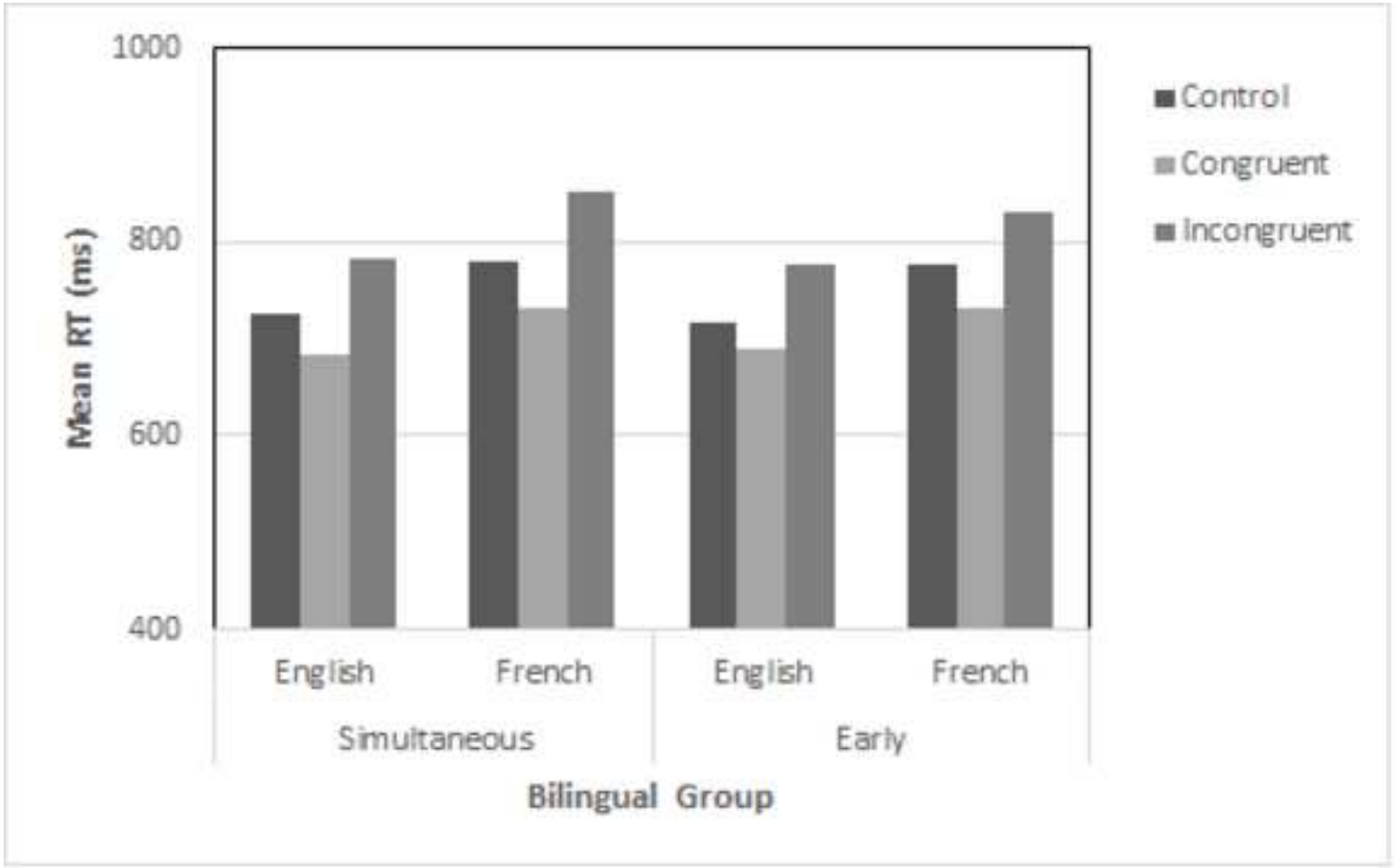

Figure

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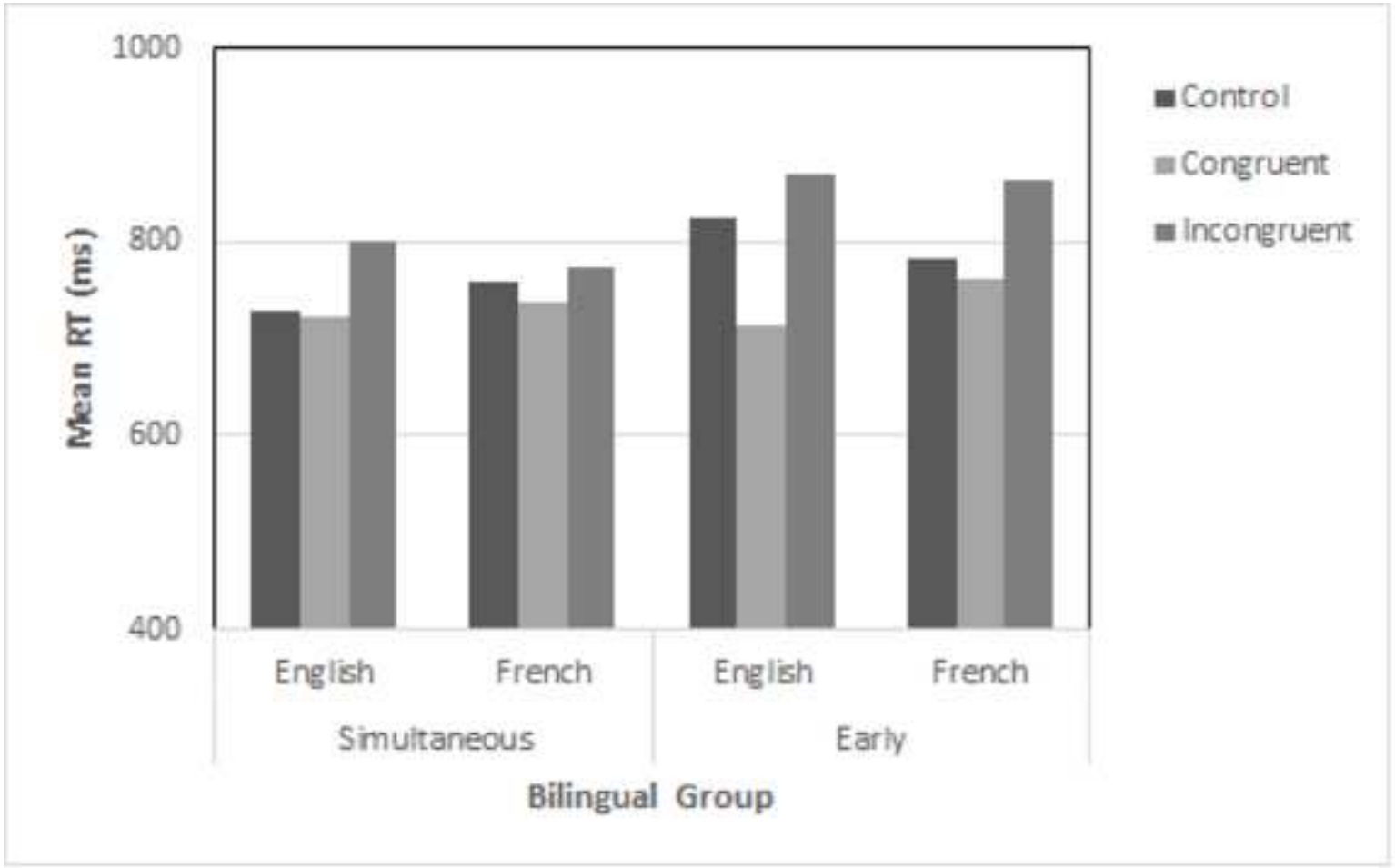

Table of Materials

Name of Material/ Equipment	Company	Catalog Number	Comments/Description
Button box	Cedrus		Button box for response; however, any response
Desktop computer (Windows OS)	Dell		Computer system for delivering stimuli; however
Presentation	Neurobehavioural Systems		Software for presenting behavioural experiment

e pad or the computer keyboard can be used to collect responses.

r, any computer, including laptops, can be used.
s; however, the experiment can be programmed using a variety of experimental software.

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August 23, 2019

Dear Editor,

We would like to thank you and the 2 reviewers for the comments on our manuscript "Examining Bilingual Language Control using the Stroop Task" JoVE60479. We have indicated below our responses to comments. We first go through the Editorial comments and then follow that with our responses to each of the reviewers.

We look forward to hearing from you shortly about further decisions on our manuscript.

Sincerely,

Laura Sabourin and Santa Vinerte

University of Ottawa

Editorial comments:

General:

1. Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues.

This has been completed.

2. Please revise lines 94-98 to avoid overlap with previously published work.

We have rewritten the paragraph.

3. For in-text formatting, corresponding reference numbers should appear as numbered superscripts after the appropriate statement(s). Please number references in the order that they appear in the manuscript.

We have reformatted the references.

4. Please use American spelling (e.g., color).

We have changed the spelling.

Protocol:

1. Please include an ethics statement before the numbered protocol steps, indicating that the protocol follows the guidelines of your institution's human research ethics committee.

A statement has been added.

2. For each protocol step, please ensure you answer the "how" question, i.e., how is the step performed? Alternatively, add references to published material specifying how to perform the protocol action. If revisions cause a step to have more than 2-3 actions and 4 sentences per step, please split into separate steps or substeps.

We have added references to previously published papers that go into greater detail about the experimental design.

Specific Protocol steps:

1. Parts 1 and 2: Would it be possible to provide sample programming as supplemental material? Additionally, more figures demonstrating these steps (either as code or conceptual diagrams) would help us visualize this. These figures could be supplemental as well.

Although we would be happy to provide the full code as supplemental material, it was written in 2011 using an older version of Neurobehavioral Systems' Presentation software, and it no longer runs correctly in the newer versions. If the old code is used in the new versions, it actually causes a glitch that stops the experiment from running to completion, and will thus not be useful to your readers.

We have added a conceptual figure showing the colour and neutral terms. Since one of the reviewers asked for more details about the actual color and neutral terms that we used, we have included this figure in the body of the manuscript, rather than as supplemental material.

Figures:

1. Figure 1: Please include a space between numbers and their corresponding units (e.g., "0 ms" instead of "0ms").

We have corrected the figure captions to include a space between the number and the unit.

Discussion:

1. As we are a methods journal, please revise the Discussion to explicitly cover the following in detail in 3–6 paragraphs with citations:

a) Critical steps within the protocol

b) Any modifications and troubleshooting of the technique

c) Any limitations of the technique

We have added more methodological information to the first paragraph of the Discussion section.

References:

1. Please ensure that the references appear as the following: [Lastname, F.I., LastName, F.I., LastName, F.I. Article Title. Source. Volume (Issue), FirstPage – LastPage (YEAR).] For more than 6 authors, list only the first author then et al.

We have reformatted the reference list.

Table of Materials:

1. Please ensure the Table of Materials has information on all materials and equipment used, especially those mentioned in the Protocol.

We have included a Table of Materials. In our case, the entire experiment can be programmed and presented with a number of different experimental software and shown on any computer, and participants can respond using any commercially-available response pad, or even just the computer keyboard. Therefore, we have only included the specialized software and equipment we used, and made a note about other elements.

Reviewers' comments:

Reviewer #1:

Manuscript Summary:

This manuscript describes a twist on the traditional bilingual Stroop task which includes a mixed-language block in addition to single-language blocks to increase the difficulty and elicit differences between groups of young adult bilinguals. This is a simple but elegant manipulation of the Stroop task to address some important issues in the bilingual executive control literature.

Major Concerns:

- Why are six color terms used, and do the authors have any suggestions for which colors should be used? Many studies use only three, but having more response options also increases the difficulty by increasing working memory demands to remember the color-button mappings. This issue should be mentioned in the Introduction.

We have included the colour terms we used, as well as including in the Introduction the rationale behind choosing 6 items, rather than three or four, as has been done by previous studies. In essence, the colour terms were increased to increase the degree of challenge for our young adult population. Based on our study results and participant feedback, even six colour terms did not present a particular challenge for our participants.

- Why are non-color terms suggested for the control condition as opposed to symbols or x's? These different control conditions produce different reaction times, which influence facilitation and interference effects. Therefore the choice of control stimuli is not trivial, and its importance should be discussed at greater length in the manuscript.

We agree that the choice of neutral stimuli is not a trivial matter, and we are actually describing this issue in detail in a Stroop meta-analysis manuscript that we are currently collaborating on. This issue was not discussed in detail in the current manuscript due to space limitations, but we have added a line to the Protocol to say that we are using words instead of symbols to obtain baseline reading times because it is a reading-based task.

- In the mixed-language block, do the authors recommend accounting for language switches between trials? Are all trials analyzed in this condition, or only trials that follow a language switch? Language switching is also known to induce cognitive costs, and should be considered and discussed here.

We are keenly aware of the issues surrounding language switching, as this is a topic that our lab also investigates, but for the purpose of this experiment, we chose to collapse across switch and non-switch trials. We are currently looking at switch and non-switch trials separately, but this is not included in the discussion here due to space limitations. We have added two sentences to mention this important issue.

Reviewer #2:

Manuscript Summary:

This paper compares the two versions of Stroop task, the single language version and the mixed language version for testing between Simultaneous bilinguals and Early bilinguals. It proposes that the various patterns were found between each group when the complexity of Stroop task increases by intermixing two languages into one block. It is suggested that these two subsets of

bilinguals should not be grouped together when the age factor is taken into account for the study of bilinguals. However, there are also some key points that the authors do not fully develop. In the following sections, the suggested points are given accordingly.

Major Concerns:

Point1: In the section of "Protocol", the authors created neutral items by presenting non-color words, but the color associate words (e.g. "tree" in green) will also induce a congruent effect. Do the authors avoid the use of these words when creating the neutral items? It's better to clarify this in the protocol. Besides, there are 6 stimuli prepared for each condition, and in the full version of the task, there are 25 stimuli presented for each condition, and does it mean there is a certain ratio for repetition for the use of some stimuli?

We have clarified the colour terms that we do use, and have noted that for the neutral items, the non-colour terms should also be non-colour associated terms.

With respect to ratios, the stimuli were randomized using NBS Presentation's randomization code, with the added restriction of no repeating stimuli. Otherwise, all stimuli were randomized completely by the program, and no number of any given stimulus per block was specified.

Point2: In the result part of lines 267 to 268"…task has been made more challenging, between-group differences start to emerge. Different patterns of facilitation and inhibition effects are found…" The authors tend to prove that the different performances of Stroop effect in the mixed-language task could be caused by different AoA for each group. However, this result could be more reliable when we know more about whether another possible confounding factor, the relative language proficiency of English and French, is controlled for each group. The reason to consider it is that in the intermixed presentation of color words in two languages, the between-language switching is largely involved. Between group differences may be influenced by balanced or unbalanced language proficiency in this mixed version. That means that large inhibition resources are exploited to suppress the dominant language when the weak language is used in the preceding trial. Therefore, when it switches to the dominant language in any of the congruency conditions, the activation level of it is reduced and that may cause the less automatic processing in the word of that dominant language. That is, the competition of attentional resources between word and color naming will be more demanding compared to the non-switching context. In that way, this latent language dominance factor may contribute to the final results of inhibition or facilitation in the mixed-version. Thus, the authors should provide more details in language proficiency of bilinguals in both groups. Are the bilinguals in the simultaneous group are balanced ones while the early group participants are dominant in English? Or Is this latent factor of language dominance fairly well matched for each group?

We have included a statement to indicate our participant groups' proficiency. Both the Simultaneous and Early bilingual groups have high proficiency in both English and French, and do not differ significantly on proficiency measures. Participants in both groups are also quite well matched for language dominance. Due to our geographic location, our participants are slightly more dominant in English, but are exposed to a high amount of written and spoken French in all aspects of their lives, and are themselves highly proficient speakers of French.

We have previously examined the role of proficiency for these groups, and found that there are no differences based on proficiency. We address language dominance in our previous article (referenced in the manuscript).

Point 3: In the section of "Discussion", the reasons behind the different patterns should be unpacked. For example, what accounts for being significantly different in the inhibition effect of Simultaneous group in the language of English while in the Early group, it was found in the facilitation effect? Does it mean that the simultaneous bilinguals compared to early bilingual have a higher automaticity of English in reading, and then the inhibition ability is much required? Since this difference shows up in the mixed context, does it mean that the Early bilinguals have little practice in the real language switching context, so that it is more demanding for them to reactivate English?

Unpacking the reasons behind the different findings is a very important aspect that needs to be figured out. And while we have some hypotheses presented in other research which we have linked we feel that the more important aspect here is the focus on the methodological issues that have resulted in the ability to separate different groups of participants. This unpacking is a crucial aspect of our lab's future research.

Minor Concerns:

In the part of Introduction, it would be better to clarify why it is necessary to examine the role of Age of Acquisition as a latent factor in bilingual advantage; why it is more specifically focused on the difference between simultaneous and early bilinguals. Otherwise, it would be to some extent abrupt or unprepared to read the division of these two groups in the section of results. The effect of AoA (a within-bilingual factor) for bilinguals on Stroop task should be described and discussed with reference to the previous literature that studied this issue.

We have added two sentences to the section on the Representative Results which explains why we are using AoA effects for illustrative purposes.