Western Undergraduate Psychology Journal

Volume 2 | Issue 1 Article 4

2014

The Influence of Executive Function on Reading Speed and Comprehension

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The Influence of Executive Function on Reading Speed and Comprehension

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This study aimed to evaluate the role that executive function plays in reading ability. Twenty-four undergraduate students at Western University performed a Flanker task to measure executive function, followed by a self-paced moving-window paradigm sentence-reading task to measure active-passive sentence-processing ability. Participants were placed in a high or low executive function group depending on their Flanker task scores. Analyses of variance (ANOVA) were performed to determine whether participants with high executive function also performed better on the sentence reading tasks. Contrary to the hypothesis, participants' sentence processing performance was not related to their Flanker task performance, which indicates that executive function does not influence reading ability.

Reading is undoubtedly one of the most important components of language. There has been a great deal of research devoted to reading, but the specific causal mechanisms that facilitate the process are still unclear. Research indicates that reading may improve general cognitive ability (Cunningham & Stanovich, 2001); therefore, it is important to continue studying the mechanisms underlying reading capabilities.

Researchers have identified several characteristics that might influence reading ability. Two such characteristics are genetics and intelligence. Research by Hohnen and Stevenson (1999) found that genes do have an impact on literacy and phonological awareness abilities among 6 and 7 year old twins. This study identified heritability coefficients of .52 for literacy and .43 for phonological awareness in MZ twins, while heritability coefficients in DZ twins were .62 and .50 for literacy and phonological awareness, respectively. Birch and Belmont (1965) performed a study examining the relationship between intelligence and reading ability in children aged 5 to 12. Results indicated that the relationship between intelligence and reading ability was moderated by age.

Ensuing research has focused on factors that influence the relationship between intelligence and reading. One of these factors is cognition: the mental process of acquiring knowledge and understanding (Swanson, Christie, & Rubadeau, 1993). Gibbs (1989) found that reading speed and comprehension were related to metacognitive abilities among deaf students. Metacognition is a high-order process that allows individuals to understand, analyze, and control their thoughts. Recent research indicates that a relationship exists between metacognition and executive functioning, which is a broad term encompassing several different cognitive processes including planning, initiating, sustaining and inhibiting thoughts and behaviors (Rothlisberger, Roebers, Cimeli, & Neuenschwander, 2012). Specifically, it was found that executive function was strongly related to metacognitive control, both cross-sectionally and longitudinally, and individual differences in both metacognitive control and executive function were related to better academic performance (Rothlisberger et al., 2012).

Previous literature has examined the specific role played by executive function in language abilities. Mann and Foy (2013)

*Initially submitted for Psychology 3184F/G at the University of Western Ontario. Research conducted with the assistance of Scotia McKinlay, Brian Shin, and Justin D'Angelo. For inquiries regarding the article, please email the author at *aharr5@uwo.ca*.

examined the role played by executive function in reading among children. The participants were tested mid-school-year on their executive function abilities using verbal and nonverbal executive function tasks. In the nonverbal executive function task, the children were asked to respond to an infrequent target sound (a dog barking), while ignoring a distractor sound (a bell ringing). Several weeks later, the researchers tested the same children using a verbal executive function task, in which the children had to listen for target stimuli while a female voice produced distractor stimuli. These tasks measured the participants' ability to suppress irrelevant information (i.e., the dog's bark and woman's voice) and attend to relevant information, a key component of executive function. At the end of the school year, participants were evaluated on their reading ability using words and pseudowords. Pseudowords were tested using the "word attack" subset of the Woodcock-Johnson (WJ) Reading Battery. This task required the participants to translate nonwords (e.g., "nat" or "lib") into sounds, which measured the children's ability to recognize printed forms. Word reading was measured using the "word identification" subset of the same test battery, and measured students' ability to recognize low frequency words. The results indicated that when age, short-term memory, and vocabulary were controlled for, inhibitory executive function related to reading ability more so than any other verbal or non-verbal skill tested. While this study provides useful information, it is not generalizable to adults. Furthermore, reading is only tested using individual words. Further research is necessary to evaluate the role that executive functioning plays in the processing of sentences, rather than just words.

Other researchers have looked more deeply at the specific role of suppression, a subset of executive functions, on language. Suppression refers to an individual's ability to ignore or disregard information. Gernsbacher and Faust (1991) performed a study where participants were tested using a variety of visual and contextual stimuli to evaluate the role of suppression in language comprehension. To begin with, 24 participants were separated into "low" and "high" comprehension groups based on their scores on a multi-media comprehension measure. In the first experiment, the researchers examined whether skilled comprehenders were better able to suppress the incorrect forms of homophones. Often, a letter string can activate a phonological sequence that activates another letter string. For example, the homophone "rows" activates the phonological sequence /roz/ which then activates another homophone, "rose". In order to understand a passage of text, these incorrect lexical forms must be suppressed.

Gernsbacher and Faust hypothesized that participants in the high comprehension group would be able to suppress incorrect lexical forms more quickly than those in the low comprehension group. Participants were presented with short sentences followed by a test word, and were required to indicate whether the test word matched the meaning of the sentence. In one quarter of the sentences, the final word was a homophone (e.g., He had lots of *patients*, for which the alternate homophone form is "patience"). On these trials, the test word was related to the alternate form of the homophone at the end of the sentence (e.g., the test word was CALM, which relates to *patience*). The researchers compared the amount of time that it took to reject the word CALM after reading the sentence "he had lots of patients", with the amount of time it took to reject CALM following the same sentence ending with a neutral word (e.g. he had lots of *students*). Findings indicated that less skilled comprehenders took significantly longer than skilled comprehenders to reject the target words related to incorrect homophones. These findings, combined with findings from three other experiments included in the article (i.e., rejecting ambiguous words, recognizing words superimposed on pictures, and recognizing absent members of scenes), led the researchers to conclude that less-skilled readers have poor

suppression abilities, which likely underlies their weaker comprehension skills.

Gernsbacher and Faust (1991) posited a theoretical framework, the Structure Building Framework (SBF), in which they hypothesize that suppression allows readers to create a mental structure that they use to process sentences. They argue that suppression allows the reader to ignore irrelevant material, and construct an understanding of sentences using only important information. SBF contends that readers begin by creating a foundation for the mental structure of a sentence, after which they map information onto the developing structure as they receive it. If the reader realizes that they have incorporated irrelevant information into the structure they were creating, they will begin developing a new structure. Within the SBF, memory nodes are the building blocks of the mental structures. Gernsbacher and Faust argue that memory nodes transmit processing signals that can either suppress or enhance the activation of other memory cells. If the new information being transmitted by the memory nodes is not consistent with the developing sentence structure, suppression will dampen the activation of those memory nodes. As this happens, enhancement will increase the activation of other memory nodes to create the new structure. Therefore, suppression becomes a key component of accurately reinterpreting written sentences.

Suppression has been researched extensively in previous literature using a variety of measures, such as words superimposed on pictures (Gernsbacher & Faust, 1991), Stroop tasks (Richeson & Shelton, 2003), and the towers of Hanoi game (Smith, Jostmann, Galinsky, & Dijk, 2008). In particular, one commonly used measure of suppression abilities is a congruent-incongruent task (Mayr, Awh, & Laurey, 2003). A congruent task is a task in which all of the stimuli are in agreement with one another (e.g., in a stroop task where the word “blue” is printed or displayed in blue). In contrast, an incongruent task is one in which the stimuli are not in agreement (e.g., in a stroop task where the word “blue” is printed or displayed in red). A congruent-incongruent task requires the participant to indicate whether the stimuli in each trial are congruent or incongruent. Congruent-incongruent trials are an effective measure of executive function because they require the participant to suppress non-relevant information (e.g., the colour of the word) in order to process the relevant information (e.g., what the word says). Therefore, individuals with strong suppression abilities will be faster to respond to congruent-incongruent trials than others. Similarly, another type of trial commonly used in studies concerning suppression is a go/no-go trial (Wittke, Spaulding, & Schechtman, 2013). In go/no-go trials, the participant is required to either perform an action or inhibit the action depending on the stimuli presented in each trial. For example, a participant may be instructed to press the space bar when a red dot appears on a computer screen, but to refrain from pressing the space bar when a green dot appears. In this scenario, the appearance of a red dot would signify a “go” trail, because it would require the participant to perform an action. Conversely, a green dot would signify a “no-go” trial, because it would require the participant to inhibit an action. In these trials participants must exercise response inhibition, and suppress the impulse to respond during “no-go” trials. Therefore, the go/no-go provides an index of both suppression and executive function ability in general.

Gernsbacher and Faust have contributed significantly to our understanding of suppression and comprehension, but their research leaves room to be expanded upon. Similar to Mann and Foy (2013), their work has focused primarily on the effect of suppression on individual words. In doing so, they neglect to evaluate the role played by suppression in sentence processing. Based on the fact that suppression allows the reader to create a mental structure and eliminate superfluous information, it seems logical that suppression ability would be helpful in processing complex sentences.

Thus far, research has not looked at the way executive function and suppression affect the processing of complex sentences. A particular type of complex sentence that might require the use of suppression is a passive sentence. Passive and active sentences refer to the two sentence structures used in the English language. When a sentence is written in the passive voice, the subject is identified toward the end of the sentence. For example, the sentence "the salesman was amused by the customers at the used car dealership" is written in the passive voice because the subject, the customers, is found after the verb (Traxler, Corina, Morford, Hafer, & Hoversten 2013). In active sentences, the subject is identified at the beginning of the sentence. For example, the sentence "the salesman amused the customers at the used car dealership" is written in the active voice because the subject, the salesman, is found before the verb. The fact that the subject is identified later makes passive sentences more difficult to process than active sentences, because the subject often changes the anticipated meaning of the sentence. When the anticipated meaning is changed, the reader must suppress their earlier interpretation of the sentence. For example, when reading the sentence "the salesman was amused by the customers", the reader may have initially assumed that someone other than the customers had amused the salesman. If so, the reader would have to suppress their earlier interpretation of the sentence. Therefore, it seems probable that suppression plays a role in passive sentence comprehension.

Previous literature has indicated that passive sentences are more difficult to process than active sentences. Street and Dabrowska (2011) performed a study examining education-specific differences in the comprehension of the passive construct. The study was conducted with two groups of adult participants: those with high academic attainment and those with low academic attainment. Both groups were presented with an online task that evaluated processing and comprehension of active and passive sentences. The results indicated that both groups processed passive sentences more slowly than active sentences. This study also assessed accuracy by asking participants to identify the "do-er" or "acted-on" after each sentence.

Participants with low academic attainment made a greater number of errors on the accuracy measure after reading passive sentences only. While Street and Dabrowska's study provides useful information about the difficulty of processing passive sentences, it leaves room for further study. The researchers do not attempt to identify the cognitive mechanisms that made it easier for the high academic attainment group to process passive sentences. It is possible that the high academic attainment group was better able to process passive sentences because of their superior executive function abilities. The present study will evaluate this idea.

The current study will examine the relationship between executive function and sentence processing. This study will focus specifically on the impact of executive function on the processing of active and passive sentences. This information can be used to improve reading in adults and foster reading abilities in children. During the study, participants completed a Flanker task that measured their executive function levels. The Flanker task is a combination of congruent-incongruent and go/no-go trials. The Flanker task was followed by a moving-window paradigm sentence-reading task that measured participants reading speeds on active and passive sentences. Executive function, as measured by the Flanker task, was the independent variable. The dependent variable was the reading times of critical words during the sentence-reading task. The researchers hypothesized that participants with high-level executive function capabilities would be better at processing active and passive sentences than participants with low-level executive function capabilities. This hypothesis is consistent with Gernsbacher and Faust's SBF. As previously

discussed, the SBF argues that the suppression of memory nodes allows the reader to reject or discard irrelevant information as they are processing a sentence. Because passive sentences are misleading, readers must often disregard information that they previously thought was relevant, and create a new mental structure. According to this model, then, suppression will play a large role in helping participants reinterpret passive sentences.

Method

Participants

The present study collected data from 24 participants, 11 of which were female and 13 of which were male. All participants were students in their third, fourth, or fifth year of undergraduate study at Western University. All participants were fluent in English. The researchers recruited friends and acquaintances to participate in the study. Participants did not receive reimbursement for their involvement in the study.

Materials

The study required participants to complete two tasks. The first was a Flanker task (an index of executive function), followed by a sentence-reading task. The Flanker task involves patterns of five symbols at a time being presented on a computer screen. Each pattern is composed of an arrow (the target) pointing left or right, surrounded by four arrows, four diamonds, or four X's. Depending on the non-target stimuli, participants must either press a button indicating the direction of the arrow or refrain from pressing any button.

Twenty active and 20 passive sentences were selected from the stimulus list of a previous study, to be used as critical stimuli (Traxler et al., 2013). Each sentence in the active voice was matched with another sentence in the passive voice (e.g., "The tourist photographed the tour guide" and "the tourist was photographed by the tour guide"). Two critical stimuli lists were prepared to reduce the likelihood of order effects. List 1 was composed of 10 active sentences and 10 passive sentences, and list 2 was composed of the remaining 10 passive and 10 active sentences. One sentence from each of the matched sentence pairs was placed on one of the two lists (i.e., the active version of a sentence would be on one list, and the passive version of the same sentence would be on the other). Of the 20 sentences on each list, 8 were followed by comprehension questions. Each list also included 40 filler sentences, 8 of which were followed by comprehension questions. Half of the comprehension questions were correct (i.e., called for a "yes" answer) and half were incorrect. To see the full stimuli list refer to Appendix A. Research has shown that people have difficultly processing the final word in sentences. To avoid this influence, there are several words following the critical words in each sentence.

Procedure

Participants were tested in a laboratory on the Western University campus. Before the study began subjects read the letter of information, and provided informed consent. Participants were seated approximately 50 cm from a computer screen, and were informed that they would begin with the Flanker task. Instructions were presented on the computer screen, informing them that several patterns of symbols would appear consecutively. At the center of each pattern would be an arrow, surrounded by arrows, diamonds, or X's. Participants were expected to indicate the direction of the arrow by pressing the "left" or "right" button on a button box. In the event that X's surrounded the arrow, the participant was instructed to not press any button. The "+" symbol appeared in the center of the screen before each trial. The "+" symbol appeared for 500 ms, then disappeared, leaving the screen blank for another 500 ms before the Flanker stimuli appeared. The task began with 16 practice trials, for which participants received

immediate feedback on their accuracy. After completing the practice trials, participants were presented with 159 critical trials. During each trial, the computer recorded the participant's accuracy and reaction time.

After completing the Flanker task, participants began the sentence-reading task. The researchers informed the participants that they would need to press the space bar to read sentences presented on the computer screen. They were also informed that they would be presented with comprehension questions to ensure their understanding of the stimuli. All of the comprehension questions required "Yes" or "No" answers, and participants indicated their answers by pressing the right (no) or left (yes) button on a button box. The sentences were presented in a self-paced moving-window paradigm. In this type of design, participants must press a button to present each word. Each time a new word appears the previous word disappears. When words are not visible, they are represented by a series of dashes (one dash for every letter in each word). Half the participants were shown List 1 and half were shown List 2. All participants saw all filler sentences. Participants were encouraged to read at a natural speed. Words were displayed in size 12, black, courier new font. Participants were presented with 60 sentences as well as 16 comprehension questions. No practice trials were presented for this task. After the participants completed a sentence (or comprehension question for the trials that included one) they were given a break. Participants were instructed to press the second button on the button box to proceed to the next sentence. During each trial, the computer recorded the accuracy of responses to comprehension questions, as well as reading times for every word in each sentence.

Results

Once data were collected for both tasks, the researchers divided the participants into two groups. The 12 participants with the fastest Flanker task scores formed the high executive function group, and the 12 with the lowest scores formed the low executive function group. This was done by performing a median split. The low executive function group was composed of participants with average reaction times greater than 456.95 ms on the Flanker task. Participants with average reaction times less than 456.95 ms made up the high executive function group. Analyses of variance (ANOVA) were performed to determine whether participants with high executive function performed better in the sentence-processing task than those in the low executive group. Reading times for the active-passive sentences were measured on three critical words in every sentence: the verb (critical region 1 – CritRegion1), the determiner (critical region 2 – CritRegion2) and the noun (critical region 3 – CritRegion3). When analyzing passive sentences, the researchers removed the word "by" from the analyses because it did not provide useful information. For example, in the sentence "the teacher was criticized by the principal", the words "criticized", "the", and "principal", were analyzed, and the word "by" was omitted.

Reading times on critical words less than 200 ms and greater than 1500 ms (2.5% of the data) were considered outliers and were excluded from the analysis. Due to an error in the labeling of the button box (the button that indicated a "no" answer was labeled "yes" and vice versa), three participants were reverse-scored for accuracy. The accuracy of responses to the comprehension questions was relatively high (78.2%). The accuracy of participants when indicating the direction of the arrow or inhibiting a response during the Flanker task was also very high (99%). ANOVAs were performed on reading times for critical words using participant (F1) and item (F2) means for the analyses. The analyses included two variables, which were sentence type (active or passive) and Flanker group (high or low). Sentence type was treated as a within-item and within-subjects variable, while Flanker group was treated as a between-item and between-

subjects variable. Researchers conducted three ANOVAs for the participant analysis, and two for the item analysis. This is because critical region 2 was the same word across all sentences ("the"), which yielded only one mean in both the passive and active sentence conditions. Therefore, ANOVAs were conducted only on critical regions 1 and 3. Means and standard deviations of response times are exhibited in Table 1.

No effect of sentence type was observed on any critical region, for participant means, CritRegion1 $F_1(1, 21) = 1.33$, *ns*, $\eta^2 = .59$, CritRegion2 $F_1(1, 21) = 1.73$, *ns*, $\eta^2 = .76$, CritRegion3 $F_1(1, 21) = 0.23$, *ns*, $\eta^2 = .11$, or for item means, CritRegion1 $F_2(1, 33) = 0.61$, *ns*, $\eta^2 = .02$, CritRegion3 $F_2(1, 33) = 0.02$, *ns,* $\eta^2 = .00$. These findings indicate that sentence type does not affect reading speed.

No between-subject effects were produced for Flanker group for participant means CritRegion1 $F_1(1, 21) = 0.33$, *ns*, $\eta^2 = .02$, CritRegion2 $F_1(1, 21) = 0.16$, *ns*, $\eta^2 = .01$, CritRegion3 $F_1(1, 21) = 0.00$, *ns,* $\eta^2 = .00$. A significant effect was observed for the Flanker group when analyzed by item means for critical region 1 $F_2(1, 33) = 5.34$, $p < .05$, $\eta^2 = .14$, but not Critical Region 3 $F_2(1, 33) = 0.00$, *ns,* $\eta^2 = .00$. These findings indicate that an effect of Flanker group may be present, but not for all participants.

No interaction of Flanker group and sentence type was observed for any critical region for participant means CritRegion1 $F_1(1, 21) = 1.12$, *ns*, $\eta^2 = .05$, CritRegion2 $F_1(1, 21) = 0.01$, *ns*, $\eta^2 = .00$, CritRegion3 $F_1(1, 21) = 0.35$, *ns*, $\eta^2 = .02$, or for item means CritRegion1 $F_2(1, 33) = 0.44$, *ns*, $\eta^2 = .01$, or for CritRegion3 $F_2(1, 33) = 0.17$, *ns,* $\eta^2 = .01$. These findings indicate that reading times on critical words do not vary between Flanker groups. While a significant effect was observed for Flanker group by items on critical region 1, the results of the study were largely non-significant. This indicates that executive function and sentence processing are not related.

Discussion

The aim of the current study was to determine whether executive function plays a role in processing active and passive sentences. The researchers hypothesized that a relationship would be identified between executive function, as measured by Flanker task scores, and active-passive processing abilities, as measured by reading times on critical words. The findings did not support the hypothesis, as there was no significant relationship observed between the Flanker and sentence processing task scores.

There are several explanations as to why the study did not support the hypothesis. It is possible that executive function is not related to reading ability, however, there are other variables of the study that may explain why a relationship was not identified. For example, the participant pool is likely to have skewed the data. All participants were university students, which indicates that they should all possess relatively strong executive function and reading abilities. As previously discussed, research by Street and Dabrowska (2011) indicated that participants with low academic attainment had greater difficulty processing passive sentences than participants with high academic attainment. Therefore, the fact that all participants in the present study were high academic achievers probably minimized any observable differences. Furthermore, the small number of participants also decreased the likelihood of finding a significant result. A greater number of participants would have increased statistical power, making a significant result more likely. Moreover, researcher and technological error may have also contributed to the current findings. For example, participants noted that the button box was not responsive at times. This indicates that reaction times were probably delayed for a few of the trials. Furthermore, some of the data had to be reverse coded. This was because several participants earned

unreasonably low scores on the comprehension questions following the sentence reading tasks. These scores indicated that participants were confused about which button indicated a "yes" or "no" response. These, and possibly other, errors may have contributed to the largely non-significant findings.

The results of the present study differed from previous findings in the literature. One reason for this may be the limited sample size; other studies included a greater number of participants. Another reason for the difference may be the type of participants involved in the study. A great deal of the previous literature was conducted on children or individuals with a physical or mental abnormality, such as deafness or a learning deficiency (e.g., Gibbs, 1989). None of the previous literature concerning executive function has included only post-secondary students. The current study is similar to previous literature in which participants were separated into "high" and "low" groups (e.g., Gernsbacher & Faust, 1991, Street & Dabrowska, 2011). However, in the current study, participants all exhibited a high level of executive function. Therefore, the division between the high and low executive function groups was somewhat arbitrary and probably didn't reflect a significant difference in ability. Another reason for the difference in findings may relate to testing methods. Most previous studies used several different measures of language and executive function, which allowed for a more accurate assessment of participants abilities. For example, Mann and Foy (2013) used two subtests of the Woodcock-Johnson (WJ) Reading Battery to measure reading ability, and two distraction conditions (verbal and nonverbal) to measure executive function. Similarly, Gernsberg and Faust (1991) included four different measures of executive function. A greater number of tests may have provided a more accurate measure of ability. This may have increased the likelihood of discovering a relationship between the variables. These findings also differ from Gernsberg and Faust's (1991) research because they do not provide support for the SBF. The SBF predicts that suppression is a key component in reinterpreting sentences. This indicates that high executive function ability should make people better at processing passive sentences because they often require reinterpretation. Non-significant findings of the current study indicate that readers form an understanding of sentences as they are reading them, instead of creating an initial structure that they must continually revise.

Findings regarding reading ability can most easily be applied to programs aimed at fostering good reading skills among children. Ensuring strong reading among children is a key concern of teachers and parents, as it is associated with many other cognitive, academic, and communicative benefits. The findings of the present study indicate that strengthening inhibitory executive function is not an effective way to improve reading. Therefore, programs developed to ensure strong reading capabilities among children should focus on improving attributes other than suppression, such as memory or attention.

While the present study did not yield significant results, previous literature indicates that executive function does influence language in some way. Therefore, future research could address the influence of executive function abilities on other types of language, specifically other complex sentences. For example, researchers could evaluate the effect of executive function on garden path sentences. Garden path sentences are structured in a way that misleads the reader, similar to passive sentences (e.g., the horse raced past the barn fell). In both sentence types, the last few words of the sentence can change the reader's earlier interpretation (Patson, Ferreira, Darowski, & Moon). Therefore, suppression may play a role in the processing of garden path sentences as well. Another type of complex sentence that may be related to executive function is one with an embedded clause. An embedded clause introduces a new topic into a sentence for the

purpose of providing extra information. For example, in the sentence "most people, particularly teenagers, do not get enough exercise", the phrase "particularly teenagers" is an embedded clause. When reading an embedded clause, the reader must process its relevance to the rest of the sentence while still focusing on the sentence's main idea (Novick, Trueswell, & Thompson-Schill, 2005). It is logical that suppression would play a role in this process. Therefore, future studies could examine whether individuals with high executive function abilities are better at reading embedded clauses. Future studies could also examine the relationship between executive function and reading in bilinguals or multi-linguals. Research has shown that multi-linguals exhibit a high degree of cognitive control because they must always inhibit one or more languages (Poarch & Hell, 2012). Therefore, it is probable that they would have a higher level of executive function than monolinguals. Future researchers could evaluate the hypothesis that multilingual individuals are better at reading complex sentences than monolinguals because of their superior executive function abilities.

Reading is an integral part of language, and cognitive function in general. Therefore, it is useful to create a better understanding of the mechanisms that facilitate reading ability. It seems very probable that executive function does play a role in sentence processing. The researchers of the present study are confident that with a different participant pool and a more refined procedure, a relationship could have been identified between these two variables. This opens the door for future research to delve deeper into the role of executive function abilities on language, as well as the qualities that influence reading ability.

First Received: 4/30/2014

Final Revision Received: 7/26/2014

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Table 1

Reading Time Means and Standard Deviations in ms

	Active Sentences				Passive Sentences			
	High EF		Low EF		High EF		Low EF	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Crit1	374	176.3	392	107.2	340	165.1	391	117.8
Crit2	331	126.0	348	59.6	316	138.9	334	63.5
Crit3	385	233.4	380	91.8	383	312.1	400	118.3

Note: Crit1, Crit2, and Crit3 refer to the 3 critical words in each sentence. High and Low EF refer to the high and low executive function groups.

Appendix A

Complete Stimulus List

Executive Function and Sentence Processing

Practice Trials:

1. The child was upset by the nurse at the clinic this morning.
    a. Was the child upset by the nurse? Y
2. The spy was smuggled out of the country in a crate.
3. The miner pushed the bartender and the people at the bar laughed.
4. The psychologist that printed the notes got lost somewhere in the basement.
    a. Did the psychologist lose the notes in the attic? N
5. The trial that the lawyer reviewed was covered by the media.
6. The scientist that the climate annoyed did not interest the reporter.
7. The professor admired the students in the biology class.
    a. Did the professor admire students in the chemistry class? N
8. The instrument that the student practiced had been around for a few months.
9. The neighbors upset the college students living next door.
    a. Did the neighbors upset the college students? Y
10. The fireman caused a small amount of damage.

Filler Trials:

1. The boy won the 500 meter race.
2. The clown at the circus scared the boy.
3. The teenagers continued to loiter in the hallway.
4. The hurricane caused the house to flood.

5. The sand on the bed is agitating.
    a. Is the dust agitating? N
6. The man did not eat his celery because he does not like the taste.
7. I played the guitar behind the counter.
8. It is not uncommon for babies to cry during the night.
    a. Is it common for babies to cry during the night? Y
9. The new laptops have touchscreens installed in them.
10. Elephants are one of the largest mammals in the world.
11. The woman prefers chocolate ice cream.
    a. Does the woman prefer vanilla ice cream? N
12. The girl had a piece of toast and eggs to eat in the morning.
13. The cook cooked the wrong order for table #24.
14. The couple went out to the fancy restaurant to celebrate their anniversary.
15. The cat played with the ball of yarn.
    a. Did the cat play with the ball of yarn? Y
16. The big man always goes to the gym at 4:30.
17. The zoo is filled with many different animals.
18. The puppy licked its owner's cheek.
19. The wife was upset after the dinner with her mother-in-law.
20. The boy has an extensive baseball card collection.
    a. Does the boy have a baseball card collection? Y
21. The girls are excited to sell their cookies.
22. The cows grazed on the pastures all day.
23. The shield on the wall is a family heirloom.

24. The mail arrived three days later after being sent.
25. The home was infested with tiny black ants.
    a. Was the home infested with tiny black rats? N
26. Camping is a hobby anybody can enjoy.
27. The townspeople helped rebuild the bridge after a flood.
28. The toolbox fell on the ground and made a loud noise.
29. The pet dog loves to eat peanut butter.
30. The farmer likes to put out hay for the horses.
31. The baby cried for food because she was hungry.
32. The bear came out of hibernation because the weather has cleared up.
33. The curator of the museum spent all day rearranging the paintings.
34. The child asked his mother for a quarter for candy.
    a. Did the child ask his mother for a loonie? N
35. The mouse crawled into the hole in the wall.
36. The soccer team won the gold medal for beating every team in the tournament.
37. The lawyer had to appear in court in the morning.
    a. Did the lawyer have to appear in court? Y
38. The tourists walked around the whole city yesterday.
39. The new car did not require gasoline to function.
40. The student failed the exam because he did not study.

Critical stimuli

Active:

1. The policeman found the child at the airport.
2. The farmer tricked the cowboy into selling the horse.
3. The player helped the coach to put away the equipment.
4. The teacher criticized the principal before the school board meeting.
5. The lion found the zebras near the watering hole.
6. The baker hired the woman to help out with the wedding.
7. The painter recruited the model after the art show.
8. The accountant visited the banker before the audit.
9. The mechanic phoned the customer after the car was repaired.
10. The lady ran over the drunk last Saturday night
11. The interpreter confused the diplomat during the treaty negotiations.
12. The scientist frightened the assistant during the thunderstorm.
13. The tourist photographed the tour guide in front of the museum.
14. The comedian liked the agent with the shiny black shoes.
15. The judge smiled at the defense attorney before the trial started.
16. The cheerleader asked the quarterback for his phone number.
17. Two ducks approached the man who had a bag of bread crumbs.
18. The pilot saluted the crew before the plane took off.
19. The salesman amused the customers at the used car dealership.
20. The mayor approached the councilman about the new library.

Passive:

1. The policeman was found by the child at the airport.
2. The farmer was tricked by the cowboy into selling the horse.

3. The player was helped by the coach to put away the equipment.
4. The teacher was criticized by the principal before the school board meeting.
5. The lion was found by the zebras by the watering hole.
6. The baker was hired by the woman to help out with the wedding.
7. The painter was recruited by the model after the art show.
8. The accountant was visited by the banker before the audit.
9. The mechanic was phoned by the customer after the car was repaired.
10. The lady was run over by the drunk last Saturday night.
11. The interpreter was confused by the diplomat during the treaty negotiations.
12. The scientist was frightened by the assistant during the thunderstorm.
13. The tourist was photographed by the tour guide in front of the museum.
14. The comedian was liked by the agent with the shiny black shoes.
15. The judge was smiled at by the defense attorney before the trial started.
16. The cheerleader was asked by the quarterback for her phone number.
17. Two ducks were approached by the man who had a bag of bread crumbs.
18. The pilot was saluted by the crew before the plane took off.
19. The salesman was amused by the customers at the used car dealership.
20. The mayor was approached by the councilman about the new library.

List One:

Actives:

1. The policeman found the child at the airport.

    Did the policeman find a lost bag? N

2. The farmer tricked the cowboy into selling the horse.

3. The player helped the coach to put away the equipment.

    Did the player help the coach? Y

4. The teacher criticized the principal before the school board meeting.

5. The lion found the zebras near the watering hole.

6. The baker hired the woman to help out with the wedding.

7. The painter recruited the model after the art show.

    Was the painter recruited by the model? N

8. The accountant visited the banker before the audit.

9. The mechanic phoned the customer after the car was repaired.

    Did the mechanic phone the customer? Y

10. The lady ran over the drunk last Saturday night.

Passives:

11. The interpreter was confused by the diplomat during the treaty negotiations.

12. The scientist was frightened by the assistant during the thunderstorm.

    Was the scientist frightened? Y

13. The tourist was photographed by the tour guide in front of the museum.

    Did the tourist photograph the statue? N

14. The comedian was liked by the agent with the shiny black shoes.

15. The judge was smiled at by the defense attorney before the trial started.

16. The cheerleader was asked by the quarterback for her phone number.

    Was the cheerleader asked by the quarterback? Y

17. Two ducks were approached by the man who had a bag of bread crumbs.

18. The pilot was saluted by the crew before the plane took off.

Was the pilot saluted by the passengers? N

19. The salesman was amused by the customers at the used car dealership.

20. The mayor was approached by the councilman about the new library.

List Two:

Actives:

1. The interpreter confused the diplomat during the treaty negotiations.

2. The scientist frightened the assistant during the thunderstorm.

Did the scientist frighten the participant? N

3. The tourist photographed the tour guide in front of the museum.

Did the tourist photograph the tour guide? Y

4. The comedian liked the agent with the shiny black shoes.

5. The judge smiled at the defense attorney before the trial started.

6. The cheerleader asked the quarterback for his phone number.

Was the cheerleader asked by the quarterback? N

7. Two ducks approached the man who had a bag of bread crumbs.

8. The pilot saluted the crew before the plane took off.

Was the crew saluted? Y

9. The salesman amused the customers at the used car dealership.

10. The mayor approached the councilman about the new library.

Passives:

11. The policeman was found by the child at the airport.

Did the child find the policeman? Y

12. The farmer was tricked by the cowboy into selling the horse.

13. The player was helped by the coach to put away the equipment.

    Did the player help the coach? N

14. The teacher was criticized by the principal before the school board meeting.

15. The lion was found by the zebras by the watering hole.

16. The baker was hired by the woman to help out with the wedding.

17. The painter was recruited by the model after the art show.

    Was the painter recruited by the model? Y

18. The accountant was visited by the banker before the audit.

19. The mechanic was phoned by the customer after the car was repaired.

    Did the mechanic phone the customer? N

20. The lady was run over by the drunk last Saturday night.