2018

The Use of a Grammaticality Judgment Task To Assess the Role of Receptive Vocabulary, Cognitive Inhibition, and Cognitive Flexibility on Syntactic Awareness

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THE USE OF A GRAMMATICALITY JUDGMENT TASK TO ASSESS THE ROLE OF RECEPTIVE VOCABULARY, COGNITIVE INHIBITION, AND COGNITIVE FLEXIBILITY ON SYNTACTIC AWARENESS

A THESIS SUBMITTED TO

THE FACULTY OF THE GRADUATE SCHOOL

IN CANDIDACY FOR THE DEGREE OF

MASTER OF ARTS

PROGRAM IN DEVELOPMENTAL PSYCHOLOGY

BY

LANETTE MAE URBIN

CHICAGO, IL

MAY 2018

ACKNOWLEDGMENTS

I would like to take the time to thank everyone who made this thesis possible, especially my committee members from the Developmental Psychology Department. Dr. Denise Davidson was instrumental to the formation of the project, conceptualizing the theoretical underpinnings of the research regarding syntactic awareness and executive functioning in bilingual children, and provided continued support, guidance, and encouragement through the process. Dr. Perla Gámez provided invaluable research experience prior to the start of the project, invaluable feedback during the course of the project, and support throughout the process.

I would also like to acknowledge the children, parents, and schools who participated in the project.

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ABSTRACT

Syntactic awareness, receptive vocabulary, and executive control (i.e., cognitive inhibition and cognitive flexibility) are robust predictors of language, literacy, and academic success (Bialystok, Craik, Klein, & Viswanathan, 2004; Davidson et al., 2010; Foursha-Stevenson & Nicoladis, 2011). In general, research demonstrates that receptive vocabulary is related to syntactic awareness (Davidson, Vanegas, Hilvert & Misiunaite, 2017; Galambos & Hakuta, 1988). There is also research to suggest that facets of executive control, such as cognitive inhibition and cognitive flexibility may also be related to syntactic awareness (Bialystok, 1986; Simard, Foucambert, & Labelle, 2013). However, receptive vocabulary, cognitive inhibition, and cognitive flexibility have only been examined separately. Thus, the current study examined the influence of receptive vocabulary, cognitive inhibition, and cognitive flexibility on syntactic awareness skill in young children (age range = 7-10 years old). Using a grammaticality judgment task with and without semantic anomalies, participants were required to identify whether a sentence was grammatically correct for sentences that were grammatically correct, grammatically incorrect, and contained semantic anomalies. Regression analyses revealed that receptive vocabulary, cognitive inhibition, and cognitive flexibility separately predicted performance on the grammaticality judgment task, whereas reaction time on measures of cognitive inhibition predicted syntactic awareness beyond the contribution of receptive vocabulary and cognitive flexibility. This study provides evidence of the importance of executive control skill (e.g., cognitive inhibition) in syntactic awareness.

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Introduction

A recent report by the National Association for Educational Progress (NAEP; 2016) indicates that the majority of U.S. fourth and eighth graders do not read with proficiency (e.g., 33% read at or above proficient levels). In addition, the U.S. ranks 17th out of 34 ranked countries in the world for reading ability (Programme for International Student Assessment; PISA, 2012), suggesting that the nation is experiencing a reading crisis. These statistics are alarming given that successful reading is critical for academic success and lifelong achievement post-graduation (Ritchie & Bates, 2013). For example, a student who struggles with reading is more likely to drop out of high school, and is less likely to attend college (Moats, 2001). Finding solutions for the nation's literacy crisis begins with identifying which skills are important for reading and how to enhance those skills.

One skill in particular that is important for reading is syntactic awareness. Syntactic awareness is the ability to reflect upon the grammatical structure of sentences (Tunmer & Grieve, 1984) and to manipulate that structure (Mokhtari & Thompson, 2006). Overwhelming research evidence suggests that levels of syntactic awareness predict reading comprehension (Demont & Gombert, 1986; Plaza & Cohen, 2003) in part because syntactic skills allow individuals to monitor their comprehension processes (Tunmer & Hoover, 1992). To illustrate the relation between syntactic awareness and reading comprehension, research by Plaza and Cohen (2003) examined syntactic awareness, reading, and spelling skills in first-grade children using an integrative hypothesis that assumed phonological, metalinguistic, and cognitive skills contribute to reading development. Their findings revealed that syntactic awareness predicted reading comprehension even when other metalinguistic skills, such as phonological awareness, were controlled. In a similar vein, Bowey (1986) examined reading skill in elementary students using a grammaticality judgment task. Students with reading difficulties had lower syntactic control, but the students that performed better on the judgment task had higher reading scores, even when controlling for receptive vocabulary ability. Moreover, syntactic awareness is a better predictor than age with regards to reading. In particular, Tunmer, Nesdale, and Wright (1987) examined syntactic awareness and reading ability in younger, more skilled readers and older poorer readers. Their results showed that younger readers performed better than older poor readers on two tasks designed to measure syntactic awareness. Given these findings, which provide evidence of the relation between syntactic awareness and reading comprehension skill, it is important to understand what skills may contribute to the development of syntactic awareness. A focus on syntactic awareness is important because it is during the early stages of reading (i.e., when students are beginning to read for comprehension) that students gain the skills required for their continued academic success (Kinnunen & Vauras, 1995).

Language Ability, Receptive Vocabulary and Syntactic Awareness

Syntactic awareness has also been shown to be related to aspects of language development, including language proficiency and receptive vocabulary (Nagy, 2007). In early language development, language ability and metalinguistic skill develop separately (Saywitz &

Cherry-Wilkinson, 1982). However, as children acquire language skill, they develop an understanding of the rules of their language and are able to master increasingly complex syntactic structures with age and exposure to more complex linguistic forms (Hakes, 1980). For example, children as young as two-and-a-half years old have a basic understanding of grammar, as they must learn how to combine simple words into meaningful phrases (Gleitman, Gleitman, & Shipley, 1972). However, the ability to recognize grammatically correct sentences and judge ungrammatical sentences as incorrect does not emerge until children are five to seven years old (e.g. Hakes, 1980; Smith & Tager-Flusberg, 1982; Tsang & Stokes, 2001), and this ability is not consistent until children are between ages seven and eight years old (Edwards & Kirkpatrick, 1999). Research by Edwards and Kirkpatrick examined syntactic awareness in a large range of children from age four to twelve and included a sample of adults for comparison. Their results demonstrated that syntactic awareness skill shifts between seven and eight years old and continues to develop into adulthood. Specifically, eight through twelve-year-olds were significantly better than four through seven-year-olds, and adults were even more proficient than the children.

Research also suggests that receptive vocabulary and syntactic awareness are inter-related (e.g., Davidson, Vanegas, Hilvert & Misiunaite, 2017; Galambos & Hakuta, 1988). The syntax of a sentence can provide important details with regards to word meanings and which pieces of information are most relevant to the meaning of words (Nagy & Gentner, 1990). Children's understanding and recognition of difficult words that they have not learned is facilitated by their knowledge of the syntactic structure, and their understanding of how to use that structure to inform the meaning of a word (Tunmer & Hoover, 1992). Research examining children's use, or misuse, of syntactic context indicates that difficulty in using the syntactic context to learn a new word comes from an inability to consider the information provided by the structure of a sentence (Goerss, Beck, and McKeown, 1999). Put more simply, because syntactic awareness is partly the ability to reflect upon the structure of sentences (Tunmer & Grieve, 1984), children who have difficulties with vocabulary learning may also lack in syntactic awareness skill (Nagy, 2007).

Relations Between Executive Control and Syntactic Awareness

Although much of the reading comprehension literature examines syntactic awareness and executive control separately, there is a subset of research that considers the impact of executive control skill on syntactic awareness. Using top-down higher order processes, children can make decisions about the syntactic structure of linguistic input, including focusing on specific structures, ignoring irrelevant information, or shifting attention between information and linguistic form (Verhoeven et al., 2011). One body of research argues that as the child matures from early childhood into the school age years, cognitive skills become more advanced and relevant to linguistic skill (Van Kleeck, 1982). That is, as the child's reasoning abilities mature, their metalinguistic awareness advances as a consequence of their better cognitive skill, and thus the child is successful on more challenging linguistic tasks.

Another body of research considers the process of acquiring linguistic awareness as requiring both an analysis of linguistic knowledge and control of attention (Bialystok, 1988; Bialystok, 2011; Simard, Fortier, & Foucambert, 2013). Bialystok's (1986) framework, supported in research by Simard, Foucambert, and Labelle (2013), addresses task characteristics of measures of syntactic awareness, and distinguishes between two important domains: analysis of knowledge and control of attention. Analysis of knowledge is either implicit, requiring more consciousness to analyze the form of language, or explicit, requiring less consciousness to analyze the language form. Control of attention is the ability to direct attention appropriately to information and use it to make a judgment quickly. Control of attention is most closely associated with cognitive inhibition, an executive control skill. Conceptualized on a continuum, Simard and colleagues suggest that when tasks draw on different levels of analysis of knowledge and control of attention, those tasks are examining syntactic awareness and cognitive inhibition (Simard et al., 2013). Additionally, during this task, participants are read sentences from all four conditions at random. For example, they may hear a sentence from condition one followed by a construction from condition four. Thus, this type of task also requires cognitive flexibility because participants are required to switch randomly between conditions of the task, as the order of sentences is varied when presented.

Grammaticality judgment tasks are those in which the participant is read a sentence and is asked to determine whether the sentence is correct or incorrect. If the sentence is determined to be incorrect, the participant is then asked to explain the error. Grammaticality judgment tasks that include semantic anomaly (e.g. the dress goes to the gym every day; Emily jumped over the moon) and require participants to explain errors require not only better syntactic awareness skill, but better inhibitory control skill in order to complete them successfully. Simply judging the structure of a sentence as correct (condition 1) for sentences without a semantic anomaly requires a low analysis of knowledge and a low level of control of attention. This is because judging grammaticality does not require one to ignore distracting information within the sentence. A little more challenging of a task is to explain, and correct, grammatically incorrect but semantically correct sentences (condition 2). This condition requires a higher analysis of knowledge (i.e., must understand the form of language with enough depth to be able to give an explanation), while still maintaining a low level of control (i.e., there is no distracting information included in the sentence).

Cognitive inhibition is implicated in conditions of a grammaticality judgment task that require the participant to ignore a distracting feature of the sentence (i.e., a semantic anomaly). Including a semantic anomaly as a condition of the grammaticality judgment task, and asking participants to judge the grammaticality of sentences that are grammatically correct (condition 3) or incorrect (condition 4) but semantically incorrect (e.g. the fish sings in the choir, or, the pencils went outside to enjoy the weather warm), increases the level of control required to successfully make correct judgments because there is a distraction (the anomaly) present in the sentence. However, if the sentence is simply a judgment, the analysis of knowledge remains low. Furthermore, asking participants to explain errors and correct sentences in the latter condition increases the level of analysis of knowledge and the control of attention.

Cognitive Inhibition, Cognitive Flexibility, and Syntactic Awareness

In selecting which cognitive skills may be important for syntactic awareness, it is not only important to consider how they each contribute to syntactic awareness individually, but also to understand how they may be conceptualized together in the mind of a child. Research on executive functions has identified three cognitive skills assumed to be working together as a unified construct. Miyake and colleagues (2000) describe this model as the Unity-Diversity model of executive functioning. They posit that there are three skills, inhibition, switching, and updating, that contribute to a single "executive control" construct, but that these skills can also be examined separately to determine their individual contribution to the larger executive control system. However, in research examining younger children around seven years of age, van der Ven, Kroesbergen, Boom, and Leseman (2012) found that the three-factor model of executive control was not appropriate. Instead, they found evidence that a two-factor model, with cognitive inhibition and cognitive flexibility, was more representative of the organization of executive control in children. The researchers argue that executive organization may be different in children than in adults, and consideration should be given to these individual executive control skills.

Cognitive inhibition and syntactic awareness. Miyake and colleagues (2000) define cognitive inhibition as an individual's ability to ignore distracting information, or inhibit a response in the presence of a stronger, but irrelevant stimuli. As children are reading a text for comprehension, they must oftentimes suppress irrelevant textual information and environmental distractions in order to focus on the most important cues in the reading, so that they may make decisions or answer questions about what was read (Borella, Carretti, & Pelegrina, 2010). Research has demonstrated that poor comprehenders display a dysfunction of inhibitory skill in comparison to good comprehenders (Cain, 2006; Chiappe, Hasher, & Siegel, 2000), indicating that inhibitory skill is important for reading comprehension. Thus, if there are deficits in cognitive inhibition, there may also be deficits in reading comprehension.

There is less research examining the specific relation between inhibitory skill and syntactic awareness than there is for inhibitory skill and reading comprehension. However, research that does exist suggests that, because individuals must be able to ignore distracting or irrelevant features of the language structure in order to understand whether or not a particular sentence structure is grammatically correct, inhibitory skill is implicated in metalinguistic awareness in general (Borella et al., 2010). Given that syntactic awareness is an important metalinguistic skill for reading comprehension, and inhibitory skill is related to good and poor comprehension, it would be advantageous for research to determine whether there is a link between syntactic awareness and cognitive inhibition. Evidence for this in the grammaticality judgment task with and without semantic anomalies comes from the semantic anomalous conditions. The participant must inhibit, or ignore, the semantic anomaly and focus on the structure of the sentence in order to make a grammaticality judgment. Thus, these conditions of the task require cognitive inhibition in order to utilize syntactic awareness skill for making judgments.

Cognitive flexibility and syntactic awareness. Cognitive flexibility, or task switching, refers to cognitive switching from one stimuli to the other (Garbin et al., 2010). Miyake and colleagues (2000) identify this skill as "shifting" rather than cognitive flexibility, and other researchers have coined this skill "attention switching" or "task switching" (e.g. Sealowitz & Frenkiel-Fishman, 2005; Prior & MacWhinney, 2010). Studies which examine the role of cognitive flexibility on reading ability maintain that there is a significant relation between the ability to flexibility switch between mental sets and the ability to read and understand complex texts. Cartwright (2002) demonstrated that performance on a task of cognitive flexibility contributed to reading comprehension skill more so than other factors such as age, decoding skill, and verbal ability. Because there are multiple components to text, such as the phonological, semantic, and syntactic structures, readers must be able to switch between these features in order to make sense of the information presented to them.

Cognitive flexibility is an important skill for syntactic awareness because children must be able to shift attention from the linguistic form (e.g.., word order, complex sentence structure, etc.) to the meaning of the content in order to fully understand the language presented to them (Owens, 1996). Particularly for the grammaticality judgment task with and without semantic anomalies, cognitive flexibility is important because sentences across four varying conditions are presented at random. An individual must be able to switch flexibly between the linguistic forms (e.g. grammatically correct or incorrect) presented and the meaning of the content (e.g., with semantic anomaly or without semantic anomaly) to make judgments on the grammaticality of the sentence. Those that are able to flexibly consider multiple forms will likely show better performance on the grammaticality judgment task with and without semantic anomalies.

The Present Study

The current study seeks to examine the role of receptive vocabulary, cognitive inhibition, and cognitive flexibility on syntactic awareness skill using a sample of elementary school children (age range = 7-10 years). Developmentally, children in this age range possess the linguistic skills required in order to complete a metalinguistic task, such as the grammaticality judgment task with and without semantic anomalies. It is predicted that their level of executive control will determine their actual ability to complete the grammaticality judgment task with and without semantic anomalies in this study because of the complexity of the task.

Researching these skills in this age range also allows us to observe how receptive vocabulary, cognitive inhibition, and cognitive flexibility relate to syntactic awareness when children are able to master basic grammaticality judgments. First, children should be able to easily make a grammaticality judgment when they must only focus on the form of the language (condition 1 of the grammaticality judgment task). However, making a judgment when both the form of the language and semantic content is manipulated will, from a metalinguistic perspective, be much more challenging. At this age, stronger switching and attention skills will be required to successfully complete the latter two conditions of the grammaticality judgement task (Van Kleeck, 1982

This study asks the following questions, 1) what levels of receptive vocabulary, cognitive inhibition, and cognitive flexibility are present in children at this age range and 2) how do those levels of receptive vocabulary, cognitive inhibition, and cognitive flexibility relate to syntactic awareness? Multiple measures of cognitive inhibition and cognitive flexibility skill will be used to examine these questions.

Methods

Participants

The participants for this study were 32 English monolingual students in elementary school, ages 7-10 (*M*= 9.344 years, *Range* = 7.17 years – 10.75 years). After acquiring IRB approval, the participants were recruited from private schools and private school summer camps in Chicago and the surrounding suburbs. Recruitment began by contacting principals and camp directors about participating in the study. After agreeing to allow their students to participate, parents at participating schools received consent forms with the details of the study that they were asked to complete, along with a demographic questionnaire (see below).

Demographics. Not all families chose to answer demographic questions. Of the 32 families in the sample, 23 (71%) answered the demographic questionnaire. Table 1 shows the demographic information obtained from these 23 parents. In general, the families in the sample who reported demographic information had high educational achievement and were from areas of high income.

Measures

Language Measures

Peabody picture vocabulary test-fourth edition. English receptive language ability was assessed using the Peabody Picture Vocabulary Test-Fourth Edition (PPVT-4; Dunn & Dunn, 2007). This is a widely used normed measure which provides a standard score, percentile rank, age equivalent, and grade equivalent for raw scores to assess language skill. The PPVT-4 has a high test-retest reliability of M = 0.93 (Dunn & Dunn, 2007).

Syntactic Awareness Measures

Grammaticality judgment task with and without semantic anomalies. The sentences and conditions used in this task can be found in Appendix B. A number of studies assessing metasyntactic awareness utilize a grammaticality judgment task (see Bialystok, Peets, & Moreno, 2014; Davidson, et al., 2017; Foursha-Stevenson & Nicoladis, 2011, Plaza & Cohen, 2003 for examples). The task used in the current study consisted of four conditions: (1) grammatically and semantically correct (i.e., The girl washes her hands before dinner), (2) grammatically incorrect and semantically correct (i.e. he his hair washes each day), (4) grammatically correct but semantically incorrect (semantic anomalies; i.e., the dress goes to the gym everyday), and (4) grammatically incorrect and semantically incorrect (semantic anomalies; i.e., the rug green barks at the door). Sentences from all four conditions were read to the participant in random order. The participant was instructed to make a grammaticality judgment for each of the sentences they heard. If a participant determined that a sentence was incorrect, regardless of whether it was actually incorrect or not, they were also asked to correct the error.

This task not only measures an individual's syntactic awareness, but it also assesses cognitive inhibition and cognitive flexibility. Especially for the conditions three and four (those with semantic anomaly), the participant must utilize cognitive inhibition to ignore the anomalous distraction in order to make a judgment about the grammaticality of the sentence. For example, in the sentence, "the dress goes to the gym every day," the participant should judge the sentence as correct based on structure if they are able to disregard the fact that the sentence simply sounds strange. Individual sentences the four conditions were presented at random to participants in this study. The task of switching randomly between conditions will require the participant to utilize cognitive flexibility skill.

Cognitive Inhibition and Cognitive Flexibility

Four measures of executive control were included in this study, two measuring cognitive inhibition and two measuring cognitive flexibility. It is advantageous for research examining executive control constructs to use a multi-measure approach because there is little agreement as to which tasks are the most representative of certain skills. The current study followed the lead of existing literature in task selection, but also considered how tasks may complement each other (i.e., verbal and nonverbal measures) and the types of information gained from each task (i.e., latency and accuracy).

Cognitive inhibition. Tasks commonly used to measure cognitive inhibition include the Stroop task (e.g. Bialystok, Craik, & Luk, 2008; Miyake et al., 2000) and the Flanker task (e.g.

Costa et al., 2008). Wide support exists for these tasks' ability to measure cognitive inhibition (e.g., Bialystok, Poarch, Lou, & Craik, 2014; Heidlmayer et al., 2014).

The Stroop task is a standard measure of cognitive inhibition used in several prior studies, including studies with children (Bialystok, 2014; Bialystok, Craik, & Luk, 2008, Dunabeitia et al., 2014). The task consists of a series of color words presented in either congruent or incongruent font color. Participants were told that they would see a series of words in various colors. They were instructed to name the font color, ignoring the word. Three conditions were presented to the participant. The first condition controlled for color naming speed in which boxes were presented in the target colors and the participant was asked to name the color as quickly as possible. The second condition was a congruent color-naming condition in which the word and font color matched. Finally, the Stroop condition (incongruent condition) presented the color names in conflicting font colors and participants were asked to name the font color as quickly as possible. The presentation order of the four conditions was counterbalanced across participants. This task was important to the study because it measured cognitive inhibition by requiring the participant to ignore a distraction (the color word) in order to focus more strongly on the target (the color itself). The task produced two types of results, time to respond to stimuli in the three conditions and accuracy of response for the three conditions.

The flanker task was used as a second measure of cognitive inhibition. Described by Bogulski and colleagues (2015), participants were required to determine whether an arrow was pointing left or right as quickly and accurately as possible. Instead of plain arrows, the child flanker task presents the arrows inside yellow fish. There were three conditions in this task: baseline, congruent, and incongruent. In the baseline condition, there was a single arrow and fish in the center of the screen and participants were asked to identify the direction of the fish, either left or right. In the congruent condition, the fish and arrow in the center of the screen was surrounded by other arrows pointing the same direction. Finally, in the incongruent condition, the fish and arrow were surrounded by other arrows that pointed in the opposite direction than the target fish and arrow. Thirty trials of each condition were presented to the participant in random order. Participants were asked to focus on the center fish and respond as quickly as possible. The Flanker was chosen because it measures cognitive inhibition by requiring a participant to focus on the target in order to make a decision about the way arrows are pointing. This task, however, does not requiring reading or language skill, and thus is used in tangent with the Stroop task, which does require the participant to read quickly. This task produced two types of results, time required to respond to the congruent and incongruent conditions and accuracy of response to the congruent and incongruent conditions.

Cognitive flexibility. There are a variety of tasks used to examine cognitive flexibility identified in the literature. Common tasks used include the Trail Making Task (Bialystok, 2010; Lu & Bigler, 2000) and the Wisconsin Card Sorting Task (Grant & Berg, 1948; Miyake et al., 2000). These tasks require participants to switch their mental focus between numbers and letters (i.e. Trail Making Task), and to shift between rules (i.e. Wisconsin Card Sorting Task).

The Wisconsin Card Sorting Task (WCST) served as a measure of cognitive flexibility in this study. This task has been used with participants as young as seven years of age through adulthood (Huizinga & van der Molen, 2007). In the print version of the task, the participant is given a deck of 64 cards, varied in color of objects on the card face, number of objects on the card face, and type of objects on the card face. The experimenter lays four cards in front of the participant and the participant begins to sort their deck. While sorting, the experimenter tells the participant whether their sorting is "right" or "wrong." When the participant makes a certain number of correct sorts, the rules for sorting change and the participant must adjust accordingly. The rules for sorting are arbitrary but could begin by color, shift to number, and then finally shift to object depicted on the card. The computerized version which was used in this research differed only in that one card, the target card, was presented above a row of four cards and the participant was asked to touch the card to which they wanted to match the target card. After making their selection, the computer either presented the word "correct" or "wrong". The participant was then given a new target card and asked to select a match. This task was important because it measured cognitive flexibility by requiring an individual to switch between sorting rules quickly.

The Trail Making Task (TMT) also measured cognitive flexibility (Arbuthnott & Frank, 2000; Bialystok & De Pape, 2009), and thus was administered to children in this study. This task consisted of four parts, Sample A, Part A, Sample B, and Part B, again presented on a computer touch screen. Circles were distributed across the screen. In Sample A, participants were shown five circles number 1-5 as practice. In Part A, the circles were numbered 1-25, and the participant was asked to use their finger to draw a line to connecting the circles in ascending order. Sample B was presented in a similar manner, but circles alternated between numbers and letters, from 1-5, as practice. For part B, the circles were numbered (1-13) and lettered (A-L) and the participant was asked to connect the circles in ascending order, alternating between the numbers and letters (i.e. 1-A-2-B-3-C, etc.) The participant was instructed to connect the circles as quickly as they were able without lifting their finger from the from the screen. The score on this task was the length of time it took to complete each part. This task was important because it also measured cognitive flexibility, but does so by requiring participants to shift between mental sets (i.e. letters of the alphabet and numbers).

Procedure

Tasks were administered to the participants individually in a quiet room provided by the schools and summer camps. Participants were tested across two days in order to avoid fatigue or boredom. All participants in the study completed the PPVT-4 and the grammaticality judgment task with and without semantic anomalies. Half of the participants received the PPVT-4 first and the other half received the grammaticality judgment task with and without semantic anomalies first in order to counterbalance the order of the language tasks.

The executive control measures were administered on a touchscreen Windows computer using the Inquisit 5 program from Millisecond Software. Using computer software allowed the presentation of stimuli to remain consistent across participants and counterbalancing of conditions within the individual tasks was automatically built into the script. In addition, utilizing computer software produced results in terms of latency (time required before responding to a condition) and accuracy, expanding the types of analyses and conclusions that can be drawn from the study.

Results

Language Measures

Peabody picture vocabulary test-4. PPVT-4 standard scores were used for analyses. The PPVT-4 standard scores are on a scale based on an average score of 100 with a standard deviation of 15. Thus, students who receive a standard score of 100 are performing at an average level for their age and, for example, those who receive a score of 115 are one standard deviation above the average. In the current sample, students' scores ranged from 78-137 (*M* = 105.47, *SD* = 14.78). There were no differences in scores across the participants' ages (7, 8, 9, and 10 years old) in this study, $F(3, 28) = 0.619$, $p > 0.05$, n.s.

Grammaticality judgment with and without semantic anomalies. The grammaticality judgement task with and without semantic anomalies consisted of four separate conditions which were mixed and counterbalanced across participants. The maximum possible score on this measure was 48, representing 12 items per each of the four conditions. Figure 1 shows the average scores for each of the four conditions. Participants demonstrated a range of scores between 13-46 (*M* = 26.47, *SD* = 8.64). Condition 1 (grammatically and semantically correct) was, as expected, very easy for the students. Scores ranged from 11-12 for this condition. All but one student achieved the maximum score, (*M* = 11.97, *SD* = 0.17). Condition 2 (grammatically incorrect and semantically correct) was more difficult. Participants scored across a wide range (1-12) but on average only did slightly worse than in the previous condition (*M* = 6.91, *SD*= 3.38). Even more challenging were the semantically anomalous conditions which required executive control. Condition 3 (grammatically correct, semantically incorrect) had a score range of 0-12 (*M* = 4.66, *SD* = 4.68) and condition 4 (grammatically incorrect, semantically incorrect) scores ranged from 0-10 (*M* = 2.94, *SD* = 3.13). In total for the anomalous conditions (maximum score of 24), participants acquired a range of scores from 0-22 with an average anomalous score of *M* = 7.59, *SD* = 7.01.

A repeated measures ANOVA was conducted to examine differences in scores for the four conditions of the grammaticality judgment task used in this study. There was a significant effect of condition on the scores of the task, Wilks' Lambda = 0.10 $F(3, 29) = 84.30$, $p < 0.001$. Paired samples t-tests were used to make post hoc comparisons between conditions. Using a Bonferroni correction, these paired samples t-test indicated that there were significant differences in scores between all conditions. Figure 1 represents these differences.

Cognitive Inhibition and Cognitive Flexibility

Cognitive inhibition. The Stroop task consisted of three conditions, control, congruent, and incongruent. The incongruent condition requires cognitive inhibition order to ignore the distraction and focus on the target response. The data are presented as latency of response (amount of time it took for participants to respond to stimuli) and accuracy in line with previous research (Rainey et al., 2016). A higher latency indicates that participants required more time to produce a response to the stimuli, and a lower latency shows that participants responded more quickly to an item. A repeated measures ANOVA was conducted to compare latency on the three Stroop task conditions. There was a significant effect of condition on the latency of responses, Wilks' Lambda = 0.67 $F(2, 29) = 7.04$, $p = 0.003$. Post hoc comparisons between conditions were conducted. As shown in Table 2, there was no significant difference between the control and congruent condition ($p > 0.05$). However, there were significant differences between the control and incongruent conditions ($p < 0.015$) and the congruent and incongruent conditions ($p < 0.001$)

A repeated measures ANOVA was also conducted to compare accuracy on the conditions of the Stroop task. There was a significant effect of condition on participants' accuracy, Wilks' Lambda = 0.49, $F(2, 29) = 15.04$, $p < 0.001$. Post hoc comparisons were conducted using paired samples *t*-tests. Significant differences were found only between the control and incongruent conditions ($p < 0.001$) and the congruent and incongruent conditions ($p < 0.001$), but not between the control and the congruent conditions ($p > 0.05$). These results are displayed in Table 3.

The Flanker task consisted of two conditions, congruent and incongruent. Congruent conditions do not require executive control in order to make a response, because there is no distracting information, but incongruent conditions require the participant to ignore distracting arrows in order to focus on the direction of the center arrow. Table 4 shows the means, standard deviations, and t-test comparisons between these two conditions. There were significant differences between the congruent and incongruent conditions for both latency ($p < 0.001$) and accuracy ($p < 0.001$).

Cognitive flexibility. Data from the WCST include number of correct card sorts, number of errors (including perseverative errors and failure to maintain set), and response time to making a sorting judgment. On average, participants made correct responses for 62% of the cards presented to them (*M* = 78.48, *SD* = 15.19) and made errors about 35% of the time (*M* = 44.71, *SD* = 18.26). Perseverative errors are those made because the participant is still following the old rule of sorting when the set changes. More perseverative errors indicate an inability to make a switch to a new rule. On average, the participants made an average of 6 perseverative errors when needing to switch the sorting rule (*M* = 6.03, *SD* = 4.56), making these types of errors 18% percent of total errors. Failure to maintain set is when a participant selects an incorrect card after having made correct responses prior to the error (thus, is not a perseverative error). Failure to maintain set errors are not due to an ability to switch, and therefore are spurious and not an indication of cognitive flexibility. The participants in this study made fewer of these errors than perseverative errors, shown in Figure 2, thus indicating that the act of switching sets and using cognitive flexibility skill was more challenging than simply maintaining a set.

Performance on the trail-making task was measured by the amount of time required for a participant to complete the trail. In this task, there were two trails. Trail A required the participant to connect numbers in ascending order and trail B required the participant to alternate numbers and letters in ascending order. A pairwise comparison of the difference between time to complete Trail A and Trail B showed a significant result, $t(22) = -2.29$, $p = 0.031$. This result is shown in Figure 3. Trail B was more difficult and required switching mental sets from numbers to letters and thus required more time for the participants to complete.

Receptive Vocabulary, Inhibition, and Flexibility on Syntactic Awareness

An additional aim of this research was to examine how the level of receptive vocabulary, cognitive inhibition and cognitive flexibility contributed to the ability to make grammaticality judgments, and more generally, syntactic awareness skill. To that end, regression analyses were conducted to examine the role of receptive vocabulary on performance on the grammaticality judgment task and executive functioning on the anomalous and, in some cases, the non-anomalous conditions of the grammaticality judgement task.

Receptive vocabulary and grammaticality judgment. Previous research has indicated a link between receptive vocabulary skill and syntactic awareness (Davidson et al., 2017). A simple linear regression was calculated to predict performance on the grammaticality judgment task based on participants' receptive vocabulary skill and a separate regression to predict performance on only the anomalous conditions of the task from receptive vocabulary score. As shown in Table 5, a significant regression equation was found for predicting scores on the grammaticality judgment task from receptive vocabulary, indicating that approximately 25% of the variance on the grammaticality judgment task can be attributed to receptive vocabulary skill. A regression analyzing the impact of receptive vocabulary skill on only the anomalous conditions of the grammaticality judgment task indicated a nonsignificant result, suggesting that other factors may also be contributing to syntactic awareness.

Inhibition, flexibility, and grammaticality judgment anomalies. The following analyses, displayed in Table 6, examined various measures of cognitive inhibition on participants' performance on the anomalous conditions (Conditions 3 and 4) for cognitive inhibition, and performance on all conditions for cognitive flexibility, of the grammaticality judgment task used in this study.

Cognitive inhibition. A linear regression was conducted to examine if reaction time on the Stroop task incongruent condition (the condition which required executive control skill) was significantly related to participants' performance on the grammaticality judgment task. As shown in Table 6, the regression equation was found to be significant, with a negative beta value. This result indicated that individuals with a lower reaction time performed better on the anomalous conditions of the grammaticality judgment task. A separate linear regression analysis predicting performance on the grammaticality judgment task from participants' accuracy on the incongruent condition of the Stroop task was conducted. Results were nonsignificant. The incongruent condition of the Flanker task also produced nonsignificant results for both reaction time and accuracy. The next set of analyses attempted to combine both aspects, latency and accuracy, of inhibition to determine if the tasks could work together to predict performance on the anomalous conditions of the grammaticality judgment task. An "inhibition latency" variable was created by taking the average of the reaction time of the incongruent Stroop condition and incongruent Flanker condition. This result was significant, indicating that those who were able to respond to stimuli more quickly on the cognitive inhibition measures were also more likely to do better on the anomalous conditions of the grammaticality judgment task. Finally, an "inhibition accuracy" variable was created by averaging the accuracy of response on the incongruent Stroop condition and incongruent Flanker condition. This result was nonsignificant, indicating that accuracy on the cognitive inhibition measures was not related to performance on the anomalous conditions of the grammaticality judgment task.

Cognitive flexibility. Cognitive flexibility for the grammaticality judgment task with and without semantic anomalies was required as participants randomly switched between conditions. Participants were required to be able to shift between grammatical, ungrammatical, and anomalous sentences with ease in order to complete the task. Thus, the dependent variable for the following regression equations is the participants' average score on the grammaticality judgment task as a whole. As seen in Table 6, a regression equation examining accuracy on the WCST and performance on the grammaticality judgment task produced nonsignificant results. Perseverative errors (number of errors produced due to a participant continuing to sort on the old rule) on the WCST are an indication of cognitive flexibility. The fewer perseverative errors one makes indicates an ability to switch quickly and flexibly to a new sorting rule. A variable for perseverative errors was created by dividing participants' perseverative errors by their total errors for these next analyses so that the scores are on a scale based on 100. A regression analysis predicting performance on the grammaticality judgment task from perseverative errors on the WCST indicated a nonsignificant result. The final set of analyses examined performance on Trail B of the trail making task and performance on the grammaticality judgment task. These results are also displayed in Table 5. Results indicated no significant prediction. However, it is important to note that time to complete Trail B alone is not as informative as the difference between the time to complete Trail A and Trail B. Creating this difference variable allows participants to be their own control for the time they required to complete the trails. In so doing, the regression analysis is significant.

Multiple regression analysis. After showing how receptive vocabulary, cognitive inhibition, and cognitive flexibility separately predicted syntactic awareness, the final analysis aimed to demonstrate how these skills together predictor performance on syntactic awareness. This analysis was conducted with the total score on the grammaticality judgment task as the dependent variable and receptive vocabulary, inhibition latency, and Trail A-B Difference as predictors. Inhibition latency was chosen as an indicator for cognitive inhibition because it combined performance on both the Stroop task and Flanker task, and was a significant predictor of performance on the grammaticality judgement task alone. Trail A-B Difference was chosen as the measure of cognitive flexibility because it was the only measure of cognitive flexibility that was significant in the single regression models examining performance on the grammaticality judgment task. As shown in Table 7, inhibition latency was significant, but receptive vocabulary and Trail A-B Difference was not, indicating that cognitive inhibition, or the ability to ignore distracting information, was more informative of participants' performance on the grammaticality judgment task than was receptive vocabulary or cognitive flexibility.

Discussion

Syntactic awareness skills are predictive of reading and language skills, which are markers of academic success. Although research has examined a variety of skills related to syntactic awareness separately, it is important to determine which skills best predict syntactic awareness ability.

Using a grammaticality judgment task, the study sought to determine how receptive vocabulary, cognitive inhibition, and cognitive flexibility were related to performance on a syntactic awareness measure, a grammaticality judgment task with and without semantic anomalies. Using regression analyses, receptive vocabulary and aspects of both cognitive inhibition and cognitive flexibility individually were shown to predict performance on the grammaticality judgment task with and without semantic anomalies. Receptive vocabulary was shown to predict performance on the whole grammaticality judgment task in an individual linear regression, but not on Conditions 3 and 4 of the task.

For both cognitive inhibition and cognitive flexibility, only measures of latency were predictive of performance on the task That is, the faster one was able to respond to stimuli, the better one performed on the grammaticality judgment task conditions. Accuracy was not a significant predictor for either executive control skill. Using multiple regression, inhibition latency remained significant, but receptive vocabulary and cognitive flexibility were no longer significant predictors of syntactic awareness.

Relation Between Executive Control and Syntactic Awareness

In line with prior research, this study found that receptive vocabulary skill predicted performance on the grammaticality judgment task with and without semantic anomalies when considering the whole task (Cain, 2007; Guo, Roehrig, & Williams, 2011; Roth, Speece, & Cooper, 2010). However, when examining only the anomalous conditions of the task, receptive vocabulary was no longer a significant predictor. This result indicated that there were other variables explaining the variance in scores on the anomalous conditions of the task. Given that executive control skills should be important for these conditions of this task, the next step was to examine whether or not these skills predicted performance on this task. We found that cognitive inhibition and cognitive flexibility did in fact explain a significant amount of variance on this task when examined alone, and cognitive inhibition remained a significant predictor when both receptive vocabulary and cognitive flexibility were entered into a model. This is important because it suggests that executive control skills, namely cognitive inhibition and cognitive flexibility, are required to complete syntactic awareness tasks.

These findings contribute to the syntactic awareness research by Simard and colleagues (2013) and Bialystok (1986), which provided evidence that syntactic awareness consists of two dimensions, analysis of knowledge and control of attention. The four conditions of the grammaticality judgment task with and without semantic anomalies required differing levels of these dimensions. The first conditions (grammatically correct/semantically correct) of the grammaticality judgment task used in this study required a low level of analysis of knowledge. Participants were asked to make a grammaticality judgment on sentence that was correct for both syntax and semantics, and almost all responded correctly. Condition 2 (grammatically incorrect/semantically correct) required a higher analysis of knowledge because they needed to be able to correctly identify and correct a syntactically incorrect sentence. This was more challenging and scores on this condition were significantly lower than scores on the first condition. The third condition (grammatically correct/semantically incorrect) required a low analysis of knowledge because the sentence was grammatically correct, like the first condition, but required a higher control of attention than the previous two conditions because participants were required to inhibit the distracting anomaly in order to make a correct judgment. This condition was significantly more difficult for participants than both the first and second conditions. Finally, the fourth condition (grammatically incorrect/semantically incorrect) required both a high analysis of knowledge, because sentences were syntactically incorrect like condition two, and a high control of attention because, like condition three, participants were required to inhibit the anomaly. Condition four was the most challenging for the participants and scores were significantly lower on this condition than any of the previous. These results suggest that, because performance on each condition was significantly different than other conditions, both analysis of knowledge and control of attention are present in the various conditions of the task, with the final condition requiring both. This indicates that executive control, namely cognitive inhibition and cognitive flexibility, are required for syntactic awareness skill.

Cognitive inhibition. Cognitive inhibition measures were predictive of performance on the grammaticality judgment task only when accounting for latency, but not for accuracy. Other research has also found this to be true for inhibition tasks in general (van der Ven et al., 2012). Confirming these results, research by Rose, Feldman, and Janowski (2011) demonstrated that processing speed is more related to executive skill than is accuracy. This is perhaps because, given an inordinate amount of time, participants may have been able to make the correct judgment regardless of the distraction. However, this is not reflective of the task characteristics or even the demands children face when making decisions about the comprehensibility of a text.

Thus, ability to make decisions quickly despite a distractor may reflect true inhibitory skill whereas accuracy does not.

We also found that latency on the Stroop task predicted performance on the grammaticality judgment task anomalous conditions but performance on the Flanker task did not. An explanation for this phenomenon may come from previous research regarding inhibitory skill. Although much of the research considers cognitive inhibition as a unitary construct, research by Colzato and colleagues (2008) examined cognitive inhibition skill as two separate constructs, “active” and “reactive” inhibition. Active inhibition is the process of deliberately ignoring a distracting information. Reactive inhibition refers to one’s ability to focus attention intentionally on a target. This study, through its use of multiple measures, may support Colzato and colleagues’ hypothesis that there are different processes involved in inhibitory skill. If it were the case that inhibitory skill was a unitary construct, both tasks should have produced similar results. However, because one task measuring inhibition predicted performance, but the other did not, it is perhaps the case that the Stroop task and the Flanker task are be tapping into different subsets of inhibition skill.

Cognitive flexibility. No variables from the WCST were predictive of performance on the grammaticality judgment task with and without semantic anomalies. In contrast, the latency difference between completion of Trail A and Trail B was significantly related to performance on the judgment task This result may also be related to processing speed describing executive function more precisely than other measurements, such as accuracy (Rose et al., 2011). The measures from the WCST included only variables of accuracy or error, but no measurement of latency of response, which could have contributed to the null results.

In a multiple regression model, the significant contributions of both of latency on the Trial Making Task and receptive vocabulary became nonsignificant when accounting for cognitive inhibition. Prior research examining syntactic awareness shows that receptive vocabulary typically explains much of the variance in this skill (e.g. Guo et al., 2011). Although research has also shown an important contribution of cognitive flexibility for metalinguistic skill (Cartwright, 2002), neither receptive vocabulary or cognitive flexibility accounted for a significant portion of variance when cognitive inhibition was considered. However, it is also possible that other measures of cognitive flexibility would have been more appropriate for assessing its relation to syntactic awareness. Research by Cartwright (2002) showed that cognitive flexibility was predictive only when the measure of flexibility reflected verbal skill. Thus, perhaps a better multiple regression model would have been one where the scores on the grammaticality judgment task with and without semantic anomalies was predicted from receptive vocabulary and a verbal measure of cognitive flexibility.

Implications of Present Findings

The implications of the findings from this research are twofold. First, methodologically and conceptually, this study adds to the extant literature on the role of syntactic awareness and executive control because of its use of multiple measures to examine indices of executive control, its use of the grammaticality judgment task with and without semantic anomalies, and its novel examination of the role of receptive vocabulary, cognitive inhibition, and cognitive flexibility on syntactic awareness.

Approaching the research questions with multiple measures allowed the researchers to determine the individual contribution from the tasks used to measure executive control on syntactic awareness. Thus, the present study provided additional evidence to suggest that certain tasks (i.e., the Stroop task and Trail-Making Task) and task characteristics (i.e., latency) provide evidence of the unique role of executive control for syntactic awareness, and other tasks/task characteristics do not (i.e., accuracy scores). Additionally, although the use of a grammaticality judgment task is not novel for syntactic awareness research (see Davidson, Raschke, & Pervez, 2010; Gaux & Gombert, 1999 for examples), and neither is a task using semantic anomaly (Rainey, Davidson, & Li-Grining, 2016), this research utilized four conditions of the judgment task, outlined from the earlier work of Bialystok (2988) and Simard and colleagues (2013) in order to assess the role of executive functioning for syntactic awareness skill.

The present study's direct examination of cognitive inhibition and cognitive flexibility on syntactic awareness is a relatively underrepresented area of research, particularly for monolingual samples. Although a wide variety of studies have examined receptive vocabulary and syntactic awareness (e.g., Davidson et al., 2017), very few studies have considered receptive vocabulary alone and together on syntactic awareness skill. Future research should assess these skills longitudinally in order to understand exactly how they may be related.

Second, these findings are relevant for researchers and practitioners developing specific interventions for children with reading difficulties. Research has shown that children with reading difficulties oftentimes have poor syntactic awareness (Demont & Gombert, 1986) or poor cognitive skills (Cain, 2006; Chiappe et al., 2000). Classroom interventions designed to assist students with reading comprehension problems focus mainly on text awareness, or rarely, methods promoting syntactic awareness. However, benefits from teacher-to-student interventions are sometimes non-existent or only marginally significant (Denton, Fletcher, Anthony, & Francis, 2006; Vaughn et al., 2010; Wanzek et al., 2013). Given that reading comprehension is a significant predictor of many critical academic and nonacademic outcomes, interventions designed to enhance students' reading ability must consider why interventions may not work for all students. Results from this research demonstrate that it is important that interventions also consider how students' cognitive skills may relate to syntactic awareness ability, and create programs designed to enhance these skills as well.

Limitations and Future Directions

One challenge in directly comparing results to other studies is the inconsistency in task selection with regards to research assessing executive control skill. There is little to no consensus among researchers about which tests are appropriate measures (van der Ven et al., 2012), thus researchers use a wide variety of tasks to measure similar constructs (e.g. Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003; Rose et al., 2011; Fuhs & Day, 2011; Weibe, Epso, & Charak, 2008). However, this yields inconsistent results across research studies. An important focus for future research, therefore, is to determine which tasks provide the best evidence for certain executive control skills, or at least, specific differences in measurement between tasks claiming to measure similar constructs.

The present study should be placed in the context of its limitations. One limitation of this study was the relatively small sample size. Some of the results were trending significance. However, finding effects and trends with such a small sample alludes to the importance of the variables. An additional problem stemming from small sample size was limitation in the types of statistical analyses that could be conducted from the data, such as more complex multiple regression analyses and factor analyses. It would be beneficial for future research to examine these measures of executive control using a confirmatory factor analysis, to determine if the inhibition measures are measuring inhibition, the flexibility measures are measuring flexibility, and that both sets are measuring something unique from each other. The present study follows the existing literature in selecting measures for certain constructs, but an empirical statistical examination of these measures would further knowledge about what they reveal about participants' executive control skills.

APPENDIX A

TABLES AND FIGURES

Table 1.
Demographic Information for Participants in the Sample

	N	Average
Age		
7	4	12.50%
8	12	37.50%
9	11	34.40%
10	5	15.60%
Mother's Education		
Some College	4	17.40%
Bachelor's Degree	10	43.50%
Master's Degree	5	21.70%
Doctorate or Professional Degree	4	17.40%
Missing Data	9	28.10%
Father's Education		
Some College	5	15.60%
Bachelor's Degree	3	9.40%
Master's Degree	8	25%
Doctorate or Professional Degree	5	15.60%
Missing Data	10	31.30%
Income		$98,751.00
Reported Income	12	37.50%
Missing Data	20	62.50%

Table 2.
Stroop task latency of response t-test results.

Pair	*t*	df	*p*
Control*Congruent	1.98	30	0.058
Control*Incongruent	-2.59	30	0.015*
Congruent*Incongruent	-3.82	30	0.001**

* = $p < 0.05$
** = $p < 0.001$

Table 3.
Stroop task response accuracy t-test results.

Pair	*t*	df	*p*
Control*Congruent	1.11	30	0.278
Control*Incongruent	5.58	30	<0.001**
Congruent*Incongruent	4.44	30	<0.001**

* = $p < 0.05$
** = $p < 0.001$

Table 4.
Flanker task latency and accuracy t-test results.

Variable	Congruent *M* (SD)	Incongruent *M* (SD)	*t*	df	*p*
Latency	839.72 (226.19)	927.49 (272.06)	-3.736	31	0.001**
Accuracy	56.88 (7.97)	53.66 (10.08)	3.541	31	0.001**

* = $p < 0.05$
** = $p < 0.001$

Table 5.
Results of the Regression Analyses of Receptive Vocabulary on the Grammaticality Judgment Task

Regression	*B*	*t*	*df*	*p*	*R2*
DV: Scores on the Grammaticality Judgment Task					
Receptive Vocabulary	0.29	3.12	31	**0.004***	0.25
DV: Scores on the Anomalous Conditions					
Receptive Vocabulary	0.15	1.8	31	0.08	0.31

* = $p < 0.05$
** = $p < 0.001$

Table 6.
Results of the Regression Analyses by Executive Function Skill

Regression	*B*	*F*	*df*	*p*	R^2
Cognitive Inhibition					
DV: Scores on the grammaticality judgment task					
Stroop Accuracy	0.23	1.67	30	0.21	0.23
Stroop Latency	-0.55	12.74	30	**0.001****	0.55
Flanker Latency	-0.23	1.67	30	0.21	0.23
Flanker Accuracy	0.34	3.86	30	0.06	0.38
Inhibition Latency	-0.54	11.98	30	**0.002***	0.54
Inhibition Accuracy	0.32	3.41	30	0.08	0.32
Cognitive Flexibility					
DV: Scores on the grammaticality judgment task					
WCST Correct	-0.09	0.22	30	0.64	0.008
WCST Perseverative Error	0.28	2.47	30	0.13	0.08
Trail B Latency	0.2	1.81	30	0.29	0.04
Trail A-B Difference	0.43	6.93	30	**0.01***	0.19

* = $p < 0.05$
** = $p < 0.001$

Table 7.

Results of the Multiple Regression Analysis with Cognitive Inhibition, Cognitive Flexibility, and Receptive Vocabulary

Step	Independent Variable	*B*	*p*	*F*	*df*	*p*	*R2*
				6.94	3,27	**0.001****	0.66
1	Receptive Vocabulary	0.24	0.14				
2	Inhibition Latency	-0.43	**0.01***				
3	Trail A-B Difference	0.27	0.07				

* = $p < 0.05$

** = $p < 0.001$

Note: DV: Scores on the grammaticality judgment task with and without semantic anomalies.

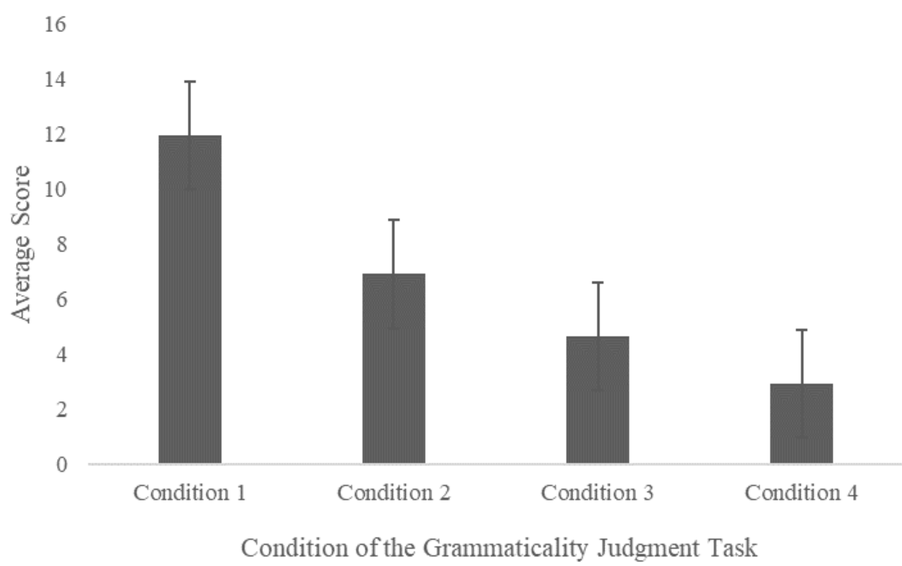

Figure 1. Differences between scores on the four conditions of the grammaticality judgment task. Significant differences were found between all conditions.

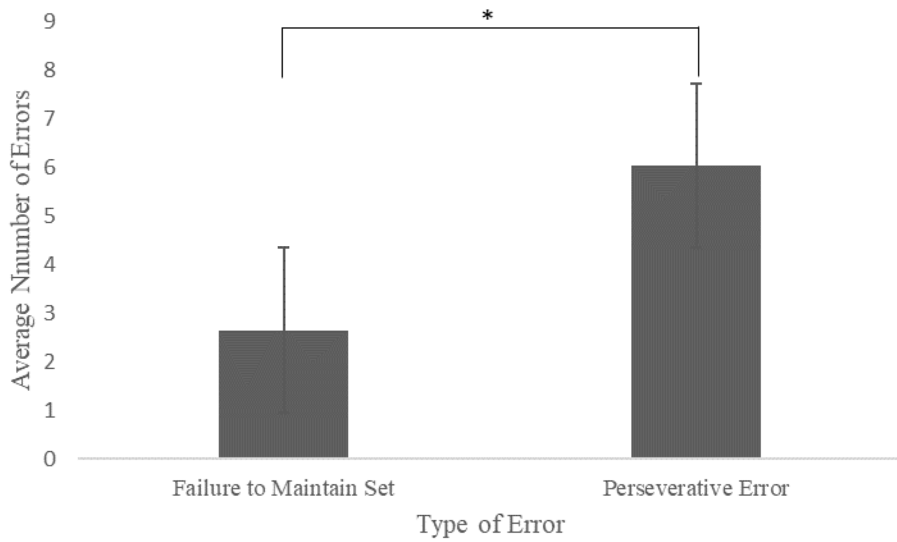

Figure 2. Mean differences between types of errors on the WCST.

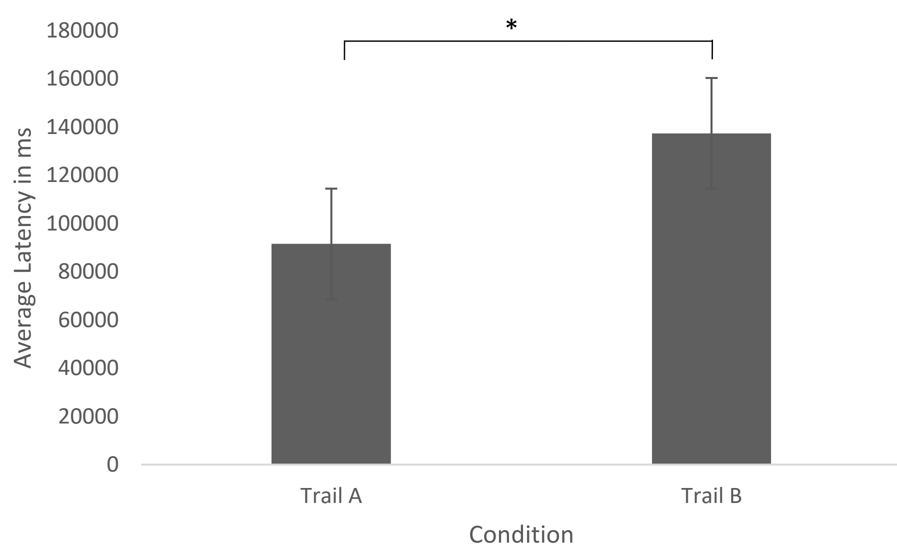

Figure 3. Mean differences in latency between Trail A and Trail B.

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VITA

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