To Fidget or Not to Fidget: The Effect of Movement on Cognition

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Abstract

Previous research suggests that there is controversy regarding the effects of fidgeting. On one hand, fidgeting has been associated with inattention. On the other hand, the act of suppressing movement may have extensive costs to cognitive abilities. Thus, allowing fidgeting might be beneficial for attention. However certain fidgeting behaviors, such as large body movements, might be disruptive in certain situations, like a classroom or an office meeting. Fidget toys have been developed that allow for smaller fidgeting movements that are non-disruptive. Most previous studies have been conducted in an elementary school classroom and have used primarily observational data. Here we examine the effects of suppression or activation of fidgeting on one's executive functioning in a college population. To suppress fidgeting, participants were told to sit completely still during testing; to activate fidgeting, participants played with a hand held fidget toy during testing; and in a neutral condition, participants were not told to suppress or activate fidgeting. We measured attentional, working memory, and response inhibition performance in easy and hard versions in of two cognitive tasks: the Stroop task, and a visual search task.

Keywords: attention, working memory, inhibition, suppression, movement, fidget-toy

To Fidget or Not to Fidget: The Effect of Movement on Cognition

It is part of human nature to move. Some movements are conscious and intentional while others are automatic and not within our conscious awareness. These automatic movements are commonly described as fidgeting. Random or rhythmic, small or large, quick or slow movements of our hands, feet, or body, typically in a mindless way, characterize fidgeting. Fidgeting occurs in everyday activities, in classrooms, meetings, and social gatherings. The frequency of fidgeting varies for each individual; some may constantly tap their fingers, twirl a pen, or bounce their legs while others are perfectly fine sitting still. There are several theories that focus on the relationship between fidgeting and cognitive abilities (i.e. attention). First, fidgeting can be a sign of inattention and decreased cognitive performance (Alderson, Rapport, Kasper, Sarver, & Kofler, 2011; Carriere, Seli, & Smilek, 2013; Farley, Risko, & Kingstone, 2013; Galton, 1885; Gligoric, Uzelac, & Krco, 2013). Second, suppression of fidgeting may hurt cognition (Wegner, Schneider, Carter, & White, 1987). Finally, fidgeting, when done non-intrusively, may help improve attention and cognitive performance (Carson, Shih, & Langer, 2001; Hunter, 2000; Levine, Schleusner, & Jensen, 2000; Rapport et al., 2009; Shukla-Mehta & Albin, 2003; Slater & French, 2010). We will discuss each of these in turn.

Fidgeting has been viewed as a sign of inattention. Teachers relentlessly tell their students to sit still and pay attention and expect that if children are sitting still, they must be paying attention (Pine, Bird, & Kirk, 2007). Not only do teachers believe in this relationship, but students do as well. When asked what exemplified inattention in a lecture setting, students responded with "fidgeting" as one of the most common indicators of decreased attention in the classroom (Gligoric et al., 2013).

Galton (as cited in Carriere et al., 2013, p. 19) described the efforts of attention in his work *The Measure of Fidget* (1885) by referring to attention as when "each person forgets his muscular weariness and skin discomfort." In essence, he notes that discomfort levels of the body are ignored when attention to the task at hand is sustained. He also suggests that boredom leads to paying attention to the bodily discomforts caused by sitting still, which in turn causes people to fidget (as cited in Carriere et al., 2013). Many researchers have found that fidgeting increases during times of decreased cognitive abilities. Carriere, Seli and Smilek (2013) found that behavior of the mind (general inattention and spontaneous mind wandering) and behavior of the body (fidgeting) were related, such that when inattention and mind wandering increased, so did fidgeting. They found that for self-report measures of attentiveness, mind wandering, and fidgeting, people tend report that they fidget more when they feel like they are losing attention or when their mind is wandering.

Other research has found that measures of fidgeting and self reports of attention were predictors of performance on a short term memory retention test; specifically, poorer memory performance was accompanied by increased fidgeting and self reports of decreased attention (Farley et al., 2013). In addition, research by Alderson and colleagues (2011) found that children tend to fidget more during cognitively demanding tasks than during simple tasks, especially for those diagnosed with Attention Deficit Hyperactivity Disorder (ADHD). Both ADHD and typically developing children increase motor activity (fidgeting) during a task that requires more cognitive effort, such as a stop-signal task, compared to a task that required less effort, such as using a Microsoft Paint program (Alderson et al., 2011).

The above research provides evidence for the negative implications of fidgeting (Alderson et al., 2011; Farley et al., 2013; Carriere et al., 2013; Galton, 1885; Gligoric et al., 2013). Clearly, children fidget more when they are not paying attention; however, the effects of fidgeting may not be so unfavorable. Instead, the act of controlling these movements could be the problem. It is possible that the processes that suppress fidgeting could consume the same resources needed for successful cognitive performance. We hypothesize that suppression of movement is closely related to suppression of thought. Research on thought suppression, specifically the study of the Ironic Process Effect (Wegner et al., 1987), suggest that if participants are told to suppress a thought, they actually think about it more often than those who were not told to suppress. Suppression of thought consumes resources that are needed to perform other cognitive tasks (Wegner et al., 1987). Similarly, when people focus on suppressing movements, their cognitive resources may be more consumed in paying attention to not moving. Given that it is detrimental to suppress thoughts and movements, it is possible that fidgeting is not the problem in and of itself. Fidgeting might actually consume fewer cognitive resources than the act of suppression. Allowing for movement could allocate more cognitive resources for the task at hand rather than engaging in the dual task of suppression of movement and paying attention. Thus, people may need to be able to move in order to better pay attention.

Examining the costs of fidgeting and suppression led researchers to discover many benefits of these subtle, mindless movements. An example of mindless fidgeting is the act of chewing gum. It is mindless in that it does not require conscious effort or attention. Wilkinson and colleagues (2002) examined this type of mindless fidgeting and found that chewing gum increased cerebral activity and improved performance on a memory test. Other researchers have also investigated the effects of chewing gum and found the same increase in cerebral activity which facilitated sustained attention (Rickman, Johnson, & Miles, 2013). These findings relate to the Cognitive Energetic Hypothesis (CEH) of ADHD, which suggests that deficits in attention are associated with low arousal and activation levels (Sergeant, 2000). It has been hypothesized that children diagnosed with ADHD increase their cortical arousal needed for a specific task by increasing their motor activity (Rapport et al., 2009). The benefits of increased arousal might also project onto a typically developing population as well. Levine and colleagues (2000) measured the percent of energy expenditure in participants using a SensorMedics 229 flow-over indirect calorimeter. They found a 54% increase of energy expenditure in those who fidget compared to those who sat still. Even more, participants who doodled during a boring task, sustained their attention longer due to increased arousal (Levine et al., 2000).

The increased arousal benefits of fidgeting may be similar to those seen as a result of exercise. Physical exercise has been known to improve health and cognition among different populations and age groups (Eshref, 1999). Exercise can help reduce stress, increase blood flow, and in turn increase oxygen flow to the brain (Hillman, Erickson, & Kramer, 2008). Physical exercise also reduces cortisol levels in the brain, which is associated with reduced stress levels and allows people to focus on a task rather than the stress of the situation (Eshref, 1999; Long & Flood, 1993). Similarly, fidgeting might influence stress levels, which in turn leads to increased cognitive performance.

Fidgeting might also be a potential means for increased attention by offering "mental breaks". A mental break can be defined as taking a break from the current task and switching to another that requires different cognitive resources (task switching) (Ariga & Lleras, 2011). We may need these mental breaks to increase sustained attention. Research shows that the goal of sustained attention decreases with time on task, which leads to attentional decrements (Ariga & Lleras, 2011; Helton & Russell, 2012). These decrements in sustained attention suggest that our cognitive resources are not adequate enough to maintain the goal of a task over long periods of time (Helton & Russell, 2012). During task switching experiments, participants perform better on a sustained attention task if it is interrupted with another task (Ariga & Lleras, 2011). This interruption eliminates the decrements and serves as a mental break, which allows for increased sustained attention. We speculate that motor movements could be considered an interruption to offer mental breaks while the task is ongoing.

Attention is an important aspect of cognition, and it is required to complete many tasks. More attention is needed if the task is novel, difficult, or stimuli are complex (Vadhan & Smothergill, 1977). This might extend to the task of sitting still, especially for those who are natural fidgeters; they may need to devote more cognitive resources into sitting still. Furthermore, since more difficult tasks require more attentional resources than easy tasks, those who are suppressing their movement may be more negatively affected during a harder task than an easy task because it requires more attention and cognitive resources.

Researchers have recognized the relationship between movement and attention, and proposed the idea that children need to move in order to enhance their attention in learning environments (Hunter, 2000). Movement has been associated with students' increased ability to attend to multiple perspectives of a single stimuli compared to sitting still (Carson et al., 2001). Students who are allowed to move around the classroom and view the information being presented from different angles, performed better than students who were told to sit still. The question now is how to activate mindless fidgeting in a non-obtrusive way.

The problem that researchers are finding to be an issue with fidgeting might not be the fidgeting itself, but the manifestation of fidgeting. For example, running around, standing, and large movements of the body may be disruptive classroom behavior while confining fidgeting to a small space is not. Teachers try to control disruptive classroom behaviors by coercing children to sit still; however, previous research has found suppression to be detrimental to cognitive performance (Wegner et al., 1987). Instead of forbidding movement in learning environments, it might be better to refocus fidgets to a confined, less disruptive behavior. Research has shown that if children have the appropriate outlet for their fidgeting, it reinforces calm on-task behavior (Shukla-Mehta & Albin, 2003). For example, Stalvey and Brasell (2006) found that students improved their academic writing scores when they played with a stress ball during their studies. These stress balls fall under the category of products that are currently being used in classrooms and learning environments called "fidget toys". Slater and French (2010) also found that when implemented into the classroom, fidget toys helped refocus students' attention to class material and away from in-class distractions. The question now is whether inducing movement and fidgeting is beneficial to cognition or if these fidget toys are merely outlets for our movements.

Since much of the research has examined school-aged children and found that fidgeting is not necessarily a negative thing (Shukla-Mehta & Albin, 2003; Slater & French, 2010), and may in fact have clear benefits, we propose to examine if activating mindless fidgeting can increase cognitive performance in a college population.

We hypothesize that if cognitive resources are freed up by allowing participants to fidget, they may be more likely to attend to the information better, and performance on cognitive tasks will improve, compared to when their fidgeting is suppressed. Previous research suggests that fidgeting increases arousal, allows for mental breaks, and therefore benefits cognition (Helton & Russell, 2012; Levine et al., 2000; Rickman et al., 2013). One way to see if fidgeting benefits cognition is to examine if executive functions are affected. Executive functions are a set of cognitive abilities that includes attention, working memory and response inhibition (Alvarez & Emory, 2006; Barkley, 1997). These cognitive abilities work together to successfully complete a cognitive based task. Here we focus on the executive functions of attention and response inhibition. Attention is important to control and manage mental processes to be able to ignore irrelevant information and select important information (Barkley, 1997). Once attention has allowed you to select the important features of a task, the information can be utilized in working memory. Response inhibition is important for us to inhibit unnecessary thoughts or behaviors in order to be able to selectively attend to and use the information (Barkley, 1997; St Clair-Thompson & Gathercole, 2006). We measured the executive functions of attention and response inhibition while participants either suppressed or activated a fidgeting behavior. The cognitive tasks we used include the Stroop task to measure attention and inhibitory control, and a visual search task to measure attention. We varied the level of difficulty in these tasks to determine if the effects of suppression or activation will differ based on the amount of cognitive resources the task requires. For example, a harder version of each task will take up more cognitive resources compared to an easier task. We predicted that suppression of movement will more negatively affect performance on difficult tasks compared to easy tasks due to the increased amount of cognitive resources needed for difficult tasks.

Previous research has either focused on self-reported measures of fidgeting and attention, or implementing fidget toys into classrooms and measuring performance. Our study, however, uses manipulation to determine the effect movement has on cognitive performance. To suppress fidgeting, one group of participants were given a fidget toy and were told that previous research has proven that sitting completely still during cognitive tasks improves performance on these tasks. To activate mindless fidgeting, a second group of participants were given a fidget toy during cognitive tasks and told that playing with a fidget toy has been proven to improve performance. We also included a third neutral condition in which participants were told to neither suppress or activate fidgeting. Based on previous research and findings, we have proposed several hypotheses: 1) Activation of movement will improve performance on cognitive tasks. 2) Suppression of movement will decrease performance on cognitive tasks. 2) Natural fidgeting behaviors would influence performance in each condition (i.e., those who naturally fidget may be more negatively affected by suppression of movements and may benefit more from activation of movements). 3) Working memory capacity (WMC) would also influence performance in each condition (i.e., higher WMC will result in better performance regardless of condition, and those with higher WMC will be less negatively affected by suppression of fidgeting).

Method

Participants

A total of 122 students at Nova Southeastern University participated in the study as volunteers or in exchange for course credit. We removed 8 participants from all analyses for various reasons (English was not their first language, equipment failure, and chewing gum). This left us with a total of 115 participants in the analysis (38 participants in the *suppression* condition, 38 participants in the *activation* condition, and 39 participants in the *neutral* condition). Informed consent was obtained before the experiment began. The experimental procedure has been approved by the Nova Southeastern University Institutional Review Board.

Materials

Cognitive tasks

Stroop task (Stroop, 1935) This task measures attention and inhibition. Participants were shown single color words written in different colors. They were instructed to verbally name the color of the word while ignoring the semantic meaning of the written word. Sometimes the color of the word was the same as the semantic meaning of the word (*congruent*), and sometimes the color of the word was different from the semantic meaning of the word (*incongruent*). Participants were instructed to respond with the color of the word out loud into a microphone as quickly as possible. To produce *easy* and *hard* versions within this task, we manipulated the proportion of congruent and incongruent trials. The *easy version* consisted of 20% *congruent* and 80% *incongruent* trials; the *difficult version* consisted of 80% *congruent* and 20% *incongruent* trials (Logan, Zbrodoff, & Williamson, 1984). The Stroop Effect is a measure of interference and is determined by calculating the difference in the time that it takes for the participant to say the *congruent* and *incongruent* trials. This task was administered on the computer through E-prime software and took approximately 10 minutes.

Visual search task (i.e. Neisser, 1964) This task measures visual attention. It requires the participant to scan the environment for a specific object (target) among other objects (distracters). The target stimulus was either a Z among distracters with *angular* qualities (i.e., X, Y, W), or among distracters with *round* qualities (i.e., O, C, U). The *angular* search was the *hard version*, and the *round* search was the *easy version*. Participants were shown a set of stimuli and were asked to identify the target within the distracters (the odd one out). Participants verbally determined as quickly as possible if the target stimulus was present or absent among the set The reaction time and accuracy was recorded to measure attention. This task was administered on the computer through E-prime software and took approximately 10 minutes. The task was a replication of Neisser (1964) and was downloaded from the internet[1].

Individual differences tasks

Automated Operation Span Task (AOSPAN; Unsworth et al., 2005) This task measures working memory capacity (WMC). Participants solved simple math problems (e.g., (2*1) + 3 = ?) while trying to remember a set of letters. Each letter is presented individually after each math problem. Participants were told to solve the math problem as quickly as possible. To solve the math problem, participants determined if the presented math problem and answer was true or false. After they determined the correct response, they were presented with a letter for 250 ms to memorize. At the end of each

[1] http://step.psy.cmu.edu/scripts/Attention/Neisser1964.html

set, participants were presented with a series of letters and were asked to determine the correct order they appeared. Participants needed to complete the math problems as quickly as possible and score at least 85% in order for their data to be used for the study. This task was administered on the computer through E-prime software and took approximately 20 minutes. We operationalized WMC as the total score[2] as recommended by Conway and colleagues (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005).

Spontaneous Activity Questionnaire (SAQ; Carriere et al., 2013) This 8-item questionnaire measured participants' perceived fidgeting behavior. This questionnaire was developed to measure non-specific behaviors in respect to how the individual is likely to fidget in everyday life. Instructions include, "Please answer the following behavior, such as 'I fidget' (scored from *rarely* to *often*), and 'Relative to other people' (scored from *a lot less* to *a lot more*)." The SAQ uses a 7-point Likert scale for all items (see Appendix A). This survey took approximately 2 minutes to complete.

Demographic Questionnaire This 10 item questionnaire consists of items (e.g., age, sex, year in school, and major) to determine demographics of each participant (see Appendix B).

Procedure

All participants completed an informed consent agreement before beginning the experiment. Then participants completed the Automated Operation Span Task (AOSPAN) to measure working memory capacity (WMC).

Participants were then randomly assigned to one of three conditions: *suppression*, *activation*, or *neutral*. In the *suppression* condition participants were given a fidget toy

[2] We did analyses on absolute score as a check, and the results were the same.

and told that research has shown that sitting completely still while holding a fidget toy improves performance on cognitive tasks. Participants in the *activation* condition were given a fidget toy and told that previous research has shown that playing with a fidget toy throughout the duration of the cognitive tasks will improve performance. The participants in the *neutral* condition were told that previous research has shown that having a fidget toy in the room during the cognitive tasks will improve performance. Participants were also be encouraged to perform to the best of their abilities and told that the participant with the highest performance will be given a gift card as a reward.

All participants then completed the two cognitive tasks; the Stroop task and visual search task. Each task contained *easy* and *hard* versions. The order of the cognitive tasks was counterbalanced with a Latin Squares design to avoid any testing effects. We used tasks that allowed the participant to respond verbally since our experiment required participants to either sit still or play with a fidget toy.

Following the completion of the cognitive tasks, all participants completed the Spontaneous Activity Questionnaire to measure perceived fidgeting in everyday life and a demographic questionnaire. Finally, they were debriefed and thanked for their participation in the study.

Results

Outlier Analyses

We performed an outlier analysis by condition for each dependent variable. Being an outlier in one dependent variable did not exclude cases from analyses on other dependent variables. For analyses using the spontaneous activity questionnaire (SAQ), 3 participants' data were not included because their responses were incomplete, leaving 112 participants to be included in the analyses using the SAQ. For analyses using working memory capacity (WMC), we only included participants who had a math performance of 85% or better leaving 102 participants to be included in analyses using the AOSPAN task. Outlier analyses were conducted separately in each condition for each dependent variable. In the Stroop and visual search tasks we defined outliers as those with z-scores greater or less than +/- 2.5. See Table 1 for the sample size used for each task by condition. Note that for the Stroop task, if either the congruent or incongruent reaction time was considered an outlier, the Stroop effect was not calculated for that participant. Also, for the visual search task, if either reaction time or accuracy had z scores greater or less than +/-2.5, both would be considered outliers.

Individual difference analyses

To verify that there were no preexisting differences between working memory capacity and natural fidgeting scores across the *suppression, activation, and neutral* conditions, we ran two one-way ANOVAs on both working memory capacity (WMC) and fidget score across condition. We found no significant differences across conditions in WMC ($F(2, 101) = 1.75$; $p = .179$) or fidget score ($F(2, 111) = .210$; $p = .811$). See Table 2. We also ran bivariate correlations between WMC and fidget score and performance on the Stroop task and the visual search task and found no correlations between WMC or fidget score on any of the cognitive tasks. See Table 3.

Stroop task

To determine if there was an effect of condition on performance on the Stroop task, we conducted separate one-way ANOVAs on the *easy* and *hard* versions of the Stroop task across the *suppression, activation, and neutral* conditions. We found no significant differences across conditions in the *hard* version of the task, $F(2, 109) = .175$, $p = .839$, $\eta_p^2 = .003$. In contrast, we found a significant difference across conditions in the *easy* version of the task, $F(2, 106) = 3.193$, $p = .045$, $\eta_p^2 = .057$. Tukey HSD post hoc analyses revealed a significant difference in the *easy* Stroop effect between the *activation* (M= 44.46, SD = 80.58) and *neutral* (M = 94.59, SD = 102.21) conditions ($p = .038$). There were no significant differences between the *suppression* (M = 77.37, SD = 74.01) and *neutral* conditions ($p = .677$) or the *suppression* and *activation* conditions ($p = .246$). See *Figure 1.*

To determine if individual differences in working memory capacity (WMC) or fidget score influenced performance on the Stroop task, we conducted separate one-way ANCOVAs on the *easy* and *hard* versions of the Stroop task across the *suppression, activation, and neutral* conditions using WMC and fidget score as covariates. We found no significant differences between conditions after controlling for WMC and fidget score for the *easy*, $F(2, 89) = 1.138$, $p = .325$, $\eta_p^2 = .025$, or *hard*, $F(2, 91) = .624$, $p = .538$, $\eta_p^2 = .014$, version of the Stroop task.

To determine if we correctly manipulated task difficulty in the Stroop task, we conducted a one-way ANOVA on the Stroop task across the *easy* and *hard* versions of the task. We found a significant difference in performance between *easy* and *hard* versions of the task, $F(1, 106) = 58.81$, $p < .001$, $\eta_p^2 = .357$. See *Figure 1.*

Visual Search Task

Due to the high accuracy in the *easy* (M = 99.76, SD = 1.13) and *hard* (M = 99.39, SD = 1.96) versions of the *absent* trial types of the visual search task, they will not be included in the analyses on visual search.

Accuracy

To determine if there was an effect of condition on accuracy in the visual search task, we conducted separate one-way ANOVAs on accuracy for the *easy* and *hard* versions across the *suppression, activation,* and *neutral* conditions. We found no significant differences in accuracy across conditions in the *easy* or *hard* versions of the task (all *p*s > .05). See *Figure 4*.

To determine if individual differences in working memory capacity (WMC) or fidget score influenced accuracy in the visual search task, we conducted separate one-way ANCOVAs on accuracy for the *easy* and *hard* versions of the visual search task across the *suppression, activation, and neutral* conditions using WMC and fidget score as covariates. We found no significant differences in accuracy between conditions after controlling for WMC and fidget score for the *easy*, $F(2, 90) = .007$, $p = .993$, $\eta_p^2 = .000$, or *hard*, $F(2, 91) = 2.127$, $p = .125$, $\eta_p^2 = .045$ version of the visual search task.

To determine if we correctly manipulated task difficulty in the visual search task, we conducted a one-way ANOVA on accuracy in visual search across the *easy* and *hard* versions of the task. We found a significant difference in performance between *easy* and *hard* versions of the task, $F(1, 107) = 22.016$, $p < .001$, $\eta_p^2 = .171$. See *Figure 4.*

Reaction Time (Present Trial Type)

To determine if there was an effect of condition on reaction time (RT) in the present trials of the visual search task, we conducted separate one-way ANOVAs on RT for the *easy* and *hard* versions across the *suppression, activation,* and *neutral* conditions. We found no significant differences in RT across conditions in the *easy* or *hard* versions of the present trials in the visual search (all *p*s > .05). See *Figure 2*.

To determine if individual differences in working memory capacity (WMC) or fidget score influenced RT in the present trials on the visual search task, we conducted separate one-way ANCOVAs on RT for the *easy* and *hard* versions of the visual search task across the *suppression, activation, and neutral* conditions using WMC and fidget score as covariates. We found no significant differences in RT between conditions after controlling for WMC and fidget score for the *easy*, $F(2, 90) = .276$, $p = .759$, $\eta_p^2 = .006$, or *hard*, $F(2, 91) = .013$, $p = .987$, $\eta_p^2 = .000$, version of the present trials in the visual search task.

To determine if we correctly manipulated task difficulty in the visual search task, we conducted a one-way ANOVA on the RT across the *easy* and *hard* versions of the present trials in the visual search task. We found a significant difference in reaction time between *easy* and *hard* versions of the task, $F(1, 107) = 106.905$, $p < .001$, $\eta_p^2 = .500$. See *Figure 2.*

Reaction Time (Absent Trial Type)

To determine if there was an effect of condition on reaction time (RT) in the absent trials of the visual search task, we conducted separate one-way ANOVAs on RT for the *easy* and *hard* versions across the *suppression, activation,* and *neutral* conditions.

We found no significant differences in RT across conditions in the *easy* or *hard* versions of the absent trials in the visual search task (all *p*s > .05). See *Figure 3*.

To determine if individual differences in working memory capacity (WMC) or fidget score influenced RT in the absent trials on the visual search task, we conducted separate one-way ANCOVAs on RT for the *easy* and *hard* versions of the visual search task across the *suppression, activation, and neutral* conditions using WMC and fidget score as covariates. We found no significant differences in RT between conditions after controlling for WMC and fidget score for the *easy*, $F(2, 88) = .737$, $p = .481$, $\eta_p^2 = .016$, or *hard*, $F(2, 88) = .649$, $p = .525$, $\eta_p^2 = .015$, version of the absent trials in the visual search task.

To determine if we correctly manipulated task difficulty in the visual search task, we conducted a one-way ANOVA on RT across the *easy* and *hard* versions of the absent trials in the visual search task. We found a significant difference in performance between *easy* and *hard* versions of the absent trial type task, $F(1, 104) = 118.182$, $p < .001$, $\eta_p^2 = .532$. See *Figure 3.*

Exploratory Analyses

Due to the small effect size ($\eta_p^2 = .057$) in the analysis on the *easy* Stroop task, we ran further analyses to see if individual differences in working memory capacity (WMC) or fidget score predicted performance in the *easy* Stroop in any of the conditions. We ran separate linear regressions on the *easy* version of the Stroop effect in the *suppression, activation,* and *neutral* conditions using either WMC or fidget score as predictors. We found that WMC was not a significant predictor of performance in any of the conditions (all *p*s > .05). In contrast, we found that fidget score predicted the Stroop effect in the *easy* version of the task in the *activation* condition only (B = .337, *t* (35) = 2.118, *p* = .041) and that it explained a significant proportion of variance, R^2 = .114, *F*(1, 36) = 4.49; *p* < .05. See Table 4. To further explain the nature of this relationship, we ran a bivariate correlation between fidget score and performance on the *easy* Stroop task selecting only for the *activation* condition. We found a significant correlation between fidget score and performance on the *easy* Stroop, *r* = .337, *p* = .041.

We speculate that participants' performance on each task would decrease towards the end of the study due to having to maintain attention for the duration of the study. Thus, to determine if performance on each task was influenced by the order in which the task was presented, we performed separate one-way ANOVAs on the order of the *easy* Stroop task for the *suppression, activation,* and *neutral* condition. We found no significant differences between task order for *suppression,* *F*(2, 34) = 2.974, *p* = .065, η_p^2 = .157, *activation*, *F*(2, 36) = 0.194, *p* = .825, η_p^2 = .011, or *neutral,* *F*(2, 36) = .337, *p* = .716, η_p^2 = .019.

Discussion

The present study provides many novel results in terms of fidgeting and cognitive performance. Consistent with previous research, we found support for our hypothesis 1) that activation of movement will improve performance on cognitive tasks; playing with a fidget toy can be beneficial to attention and response inhibition as measured by the Stroop task. We found that participants in the *activation* condition performed better than those in the *neutral* condition. However, we did not find any differences across the conditions in the visual search task. We did not find support for our hypothesis 2) that suppression of movement would decrease performance on cognitive tasks. We did find support for our hypothesis 3) that natural fidgeting behaviors would influence performance in each condition; however, we did not find support for our hypothesis 3) that working memory capacity (WMC) would also influence performance in each condition. In addition, we did not find that participants would benefit more from *activation* of fidgeting in a *hard* task compared to an *easy* task. Across the *suppression*, *activation*, and *neutral* conditions, there were no significant differences between the performances in the *hard* version of the Stroop task. We speculate that this is due to the *hard* version being too difficult regardless of condition. This is supported by results indicating a significant decrease in performance in the hard version compared to the easy version in all conditions.

One reason why we found an effect in the Stroop task, but not the visual search task, might be due to the nature of each task. Visual search requires bottom up, automatic processing, while the Stroop task requires top down, controlled processing. Top down responses are controlled by the intentions of the participant (Theeuwes, 2010).

The Stroop task evaluates flexibility in the control of cognitive processes and behavior (Stroop, 1935). Controlled processing is needed on *incongruent* trials of the task where participants must use cognitive control mechanisms to suppress automatic word reading and activate color-naming processes in order to respond correctly (Bugg & Jacoby, 2008). On the other hand, bottom up, responses are determined by the environment and occur in a passive, automatic way, and require fewer resources than a controlled, or top down response (Theeuwes, 2010). In our visual search task, participants were required to search for a target letter among distractors. This was a simple feature search, and there was no required manipulation of the information; participants were asked to simply identify if the letter was present or absent on the screen. Future research might consider using a conjunction search task, as this type of search task requires more controlled processing, and thus might be similar to the Stroop task in this regard (Theeuwes, 2010).

In contrast to the vast amount of research suggesting that suppression is detrimental to cognitive performance and attention (Wegner, Schneider, Carter, & White, 1987), we did not find a significant effect of *suppression* across any of the cognitive tasks. One explanation for this null result could be due to the fact that neither the Stroop task nor the visual search task required participants to remain focused over a long period of time. As previously noted, sustained attention decreases with extended time on task (Ariga & Lleras, 2011; Helton & Russell, 2012). Further, research on sustained attention suggests that mental breaks are needed to maintain attention (Ariga & Lleras, 2011). Mental breaks can be defined as taking a break from the current task and switching to another task that requires different cognitive resources (task switching) (Ariga & Lleras, 2011). Our cognitive tasks were short in duration and perhaps attention was not lost due to the rapid switching between tasks during our experiment; each task lasted approximately 5-10 minutes and participants were allowed a short break to stretch between tasks. When tasks require sustained attention, the act of sitting still may become more demanding. Perhaps due to the short duration of our tasks, participants did not have the chance for their mind to wander and thus, lose attention. People tend to report that they fidget more when they feel like they are losing attention or when their mind is wandering (Carriere et al., 2013). The idea that a sustained attention task would be more influenced by suppression of movement is supported by our analyses on task order. Our data, although trending towards significance, suggests while participants are asked to suppress movement, they performed worse in the *easy* Stroop task when it was the last task presented in the hour during the study. Thus, towards the end of the study, participants have had to sustain their attention longer and sitting still may become more demanding. Future research should implement a longer task such as a longer version of the Stroop task or the sustained attention to response task in which sustained attention would be an issue.

Another reason for the null effect of suppression on cognitive performance could be that our sample was drawn from a population of college students, who are at an age where sitting still is not as demanding of a task. As individuals grow up, sitting still becomes the norm, especially in formal situations. Participants may have viewed the lab as a more formal situation and could have been naturally suppressing their movements due to the social norms of sitting still. Previous studies with kids find that they can't sit still, especially during difficult tasks, and thus their attention wavers (Hunter, 2000). It could be that children who are still developing their executive functions may have fewer resources to devote to both suppression of movement and the task at hand. This is further supported by the symptoms of attention deficit disorder (ADD). Children who have ADD typically show more of the hyperactivity symptoms compared to adults with ADD. This suggests that even those with attention disorders have less issues sitting still as they get older. We hypothesize that suppression may have a stronger effect in a younger population where sitting still and executive functions are developing processes.

If suppression of movement does in fact take up cognitive resources needed to perform the given tasks, and activation of movement frees up those resources, we would expect that working memory capacity (WMC) would influence the effect of suppression or activation on performance. Those with higher WMC should have more resources to devote to both suppression and the task at hand compared to those with lower WMC who may be more negatively affected by suppression due to fewer resources to devote to both. However, WMC did not predict performance on any of our cognitive tasks. Furthermore, there was no correlation between WMC and performance on the cognitive tasks, as many others have found (Engle, 2002). We hold to our original hypotheses that WMC should influence performance based on previous research suggesting that suppression uses up cognitive resources and thus we suggest that future research use additional measures to obtain a more accurate and comprehensive account of WMC.

Another individual difference that we hypothesized would influence performance is natural fidgeting behavior. We hypothesized that regardless of natural fidgeting level, doing something unnatural would take up more resources and negatively impact performance on cognitive task. In essence, participants who believed themselves to be natural "fidgeters" would benefit more from *activation* of movement and perhaps more negatively affected from *suppression* of those movements. On the other hand, those who identified as natural "non-fidgeters" would not be as negatively affected by *suppression*, but may be more negatively affected by *activation*. In this case, we would expect that individual responses on the self reported fidgeting scale (SAQ) would influence performance in each condition. We did not find support for this in our analyses.

We speculate that we did not find a significant difference across conditions while controlling for WMC and fidget score due to the small effect size. Thus, we explored further into how these individual differences influenced performance. We performed exploratory analyses only on the *easy* Stroop task given that no other task yielded significant differences across conditions. In our exploratory analyses we found that fidget score does predict performance in the *activation* condition on the *easy* Stroop task but not in any of the other conditions. Thus, perceived natural fidgeting behavior does predict performance when participants are playing with the fidget toy. This relationship is counterintuitive at first; we found that naturally high fidgeters had a greater Stroop effect (in the *easy*, but not the *hard*, version of the task) than naturally low fidgeters. Said another way the more someone identified as a fidgeter, the poorer they performed when they were asked to fidget using the fidget toy. A possible explanation to this could be that the way fidgeting was activated in this task – by the use of a fidget toy – might be unnatural to those who are *high* fidgeters. Future research should explore the idea that those who identify as fidgeters may have a certain way they typically fidget Thus, it may be important to take into account the type of fidgeting that people engage in whether it be foot tapping, hair twirling, or another form of fidgeting to get a better understanding of the effects of *activation* or *suppression* of these types of movement.

Related, we measured a person's self-perception of fidgeting behavior using a survey. Since behavior is very difficult to objectively measure using self-report techniques, future research should implement a more objective form of measuring fidgeting behavior either through video recording participant's behavior or measuring it through an actigraph device to gain a more accurate account of individual natural fidgeting behaviors.

Another possible explanation for the overall pattern of performance in the *easy* Stroop task across conditions could be due to the placebo effect in each condition. Each participant was informed that the condition they were in would increase performance on the task. The placebo effect could differ from condition to condition due to the believability of the task. For example, participants who were told that the toy sitting on the desk in front of them would increase their performance on the task may be less likely to believe compared to *suppression* or *activation* of the toy. Thus, the decrease in the Stroop effect in the *activation* condition could be supplemented by a stronger placebo effect. Future research could measure the effect of *activation* and *suppression* without the placebo to see if the results were due to the fidgeting itself, the placebo effect, or a combination of both.

The current study suggests that while allowing fidgeting may help with an inhibitory and attention task depending on your level of natural fidgeting, these results suggest that sitting still may not be as detrimental as previously reported. Despite our findings that working memory capacity does not influence performance, we theorize that future research should be conducted on a population with either cognitive deficits or children who are still developing executive functions. Furthermore, we suggest that future research be done implementing a longer task as our findings suggest sustained attention may be more influenced by suppression. However, our results have implications for the classroom where we have at least partial support for allowing kids to move about in order to increase their attention. More research is needed to determine the exact nature of fidgeting that is helpful.

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Table 1. *Sample size for each task by condition*

	Stroop		Visual Search			
	Easy	Hard	Easy		Hard	
			Present	Absent	Present	Absent
Suppression	35	36	37	36	37	36
Activation	37	38	35	35	36	36
Neutral	37	38	37	37	39	37
Total	109	112	109	108	112	109

Table 2. *Mean and standard error (stderr) of working memory capacity (WMC) and fidget score across conditions.*

		n	mean	stderr
WMC	Suppression	36	54.33	2.34
	Activation	34	59.53	1.51
	Neutral	32	55.31	2.32
Fidget Score	Suppression	36	3.96	0.22
	Activation	38	3.77	0.23
	Neutral	38	3.96	0.25

Table 3. *Summary of correlations between working memory capacity (WMC) and fidget scores with the Stroop effect in the Stroop task and reaction time (RT) and accuracy in the visual search task.*

			WMC			Fidget Score		
Task	Dependent measure	Task type	Pearson Correlation	*p*	n	Pearson Correlation	*p*	n
Stroop	Stroop effect	Easy	-0.03	0.78	97	0.11	0.25	106
		Hard	0.15	0.15	99	-0.02	0.88	109
Visual search	RT	Easy, Absent	-0.14	0.16	96	0.08	0.4	105
		Easy, Present	-0.04	0.68	98	0.17	0.08	106
		Hard, Absent	-0.15	0.15	96	0.08	0.41	106
		Hard, Present	-0.13	0.2	99	0.02	0.84	109
	Accuracy	Easy, Absent	0.07	0.53	96	0.07	0.51	105
		Easy, Present	0.16	0.12	98	-0.03	0.73	106
		Hard, Absent	-0.03	0.74	96	-0.07	0.5	106
		Hard, Present	-0.03	0.79	99	-0.16	0.09	109

Table 4. *Summary of linear regression statistics for the predictor variables in the suppression, activation, and neutral conditions in the easy and hard versions of the Stroop task.*

Condition	Predictor Variable	B	SE B	ß	t	*p*
	WMC	0.64	0.96	0.12	0.67	0.51
Suppression	Fidget Score	-8.94	11.18	-0.14	-0.80	0.43
	WMC	0.76	1.66	0.08	0.46	0.65
Activation	Fidget Score	19.36	9.14	0.34	2.12	0.04 *
	WMC	-1.94	1.40	-0.25	1.39	0.18
Neutral	Fidget Score	-3.54	11.91	-0.05	-0.30	0.77

Note. * $p < .05$

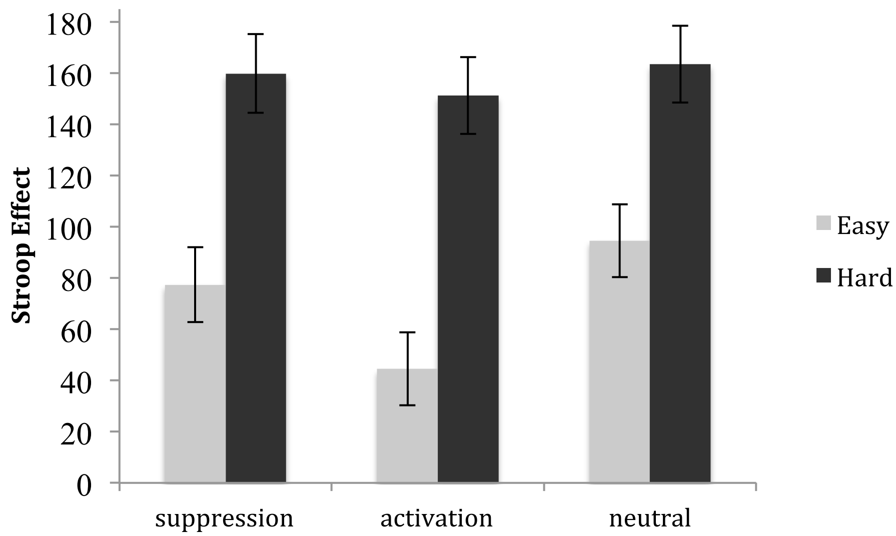

Figure 1. Stroop effect across *suppression, activation,* and *neutral* conditions for the *easy* and *hard* versions on the Stroop task. Error bars are standard errors.

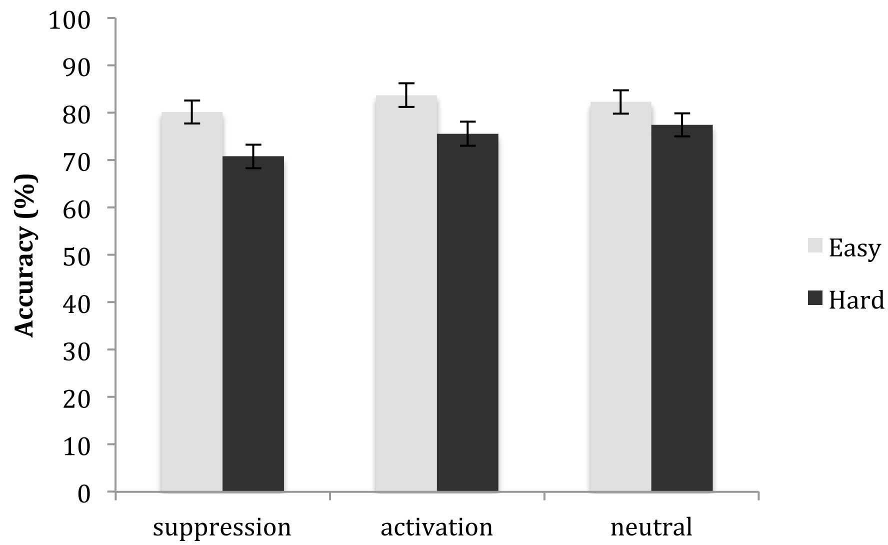

Figure 2. Accuracy across *suppression, activation,* and *neutral* conditions for the *easy* and *hard* versions on the present trial types of the visual search task. Error bars are standard errors.

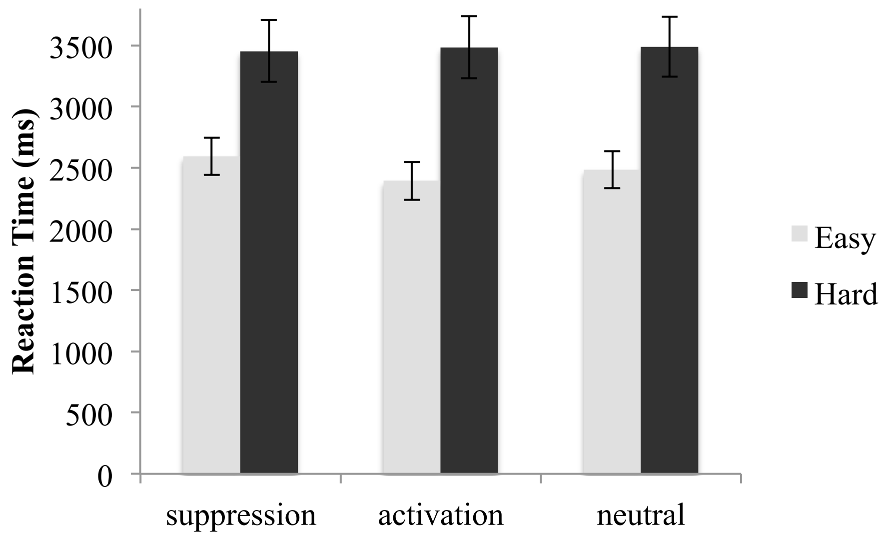

Figure 3. Reaction times on *present* trial types across *suppression, activation,* and *neutral* conditions for the *easy* and *hard* versions on the visual search task. Error bars are standard errors.

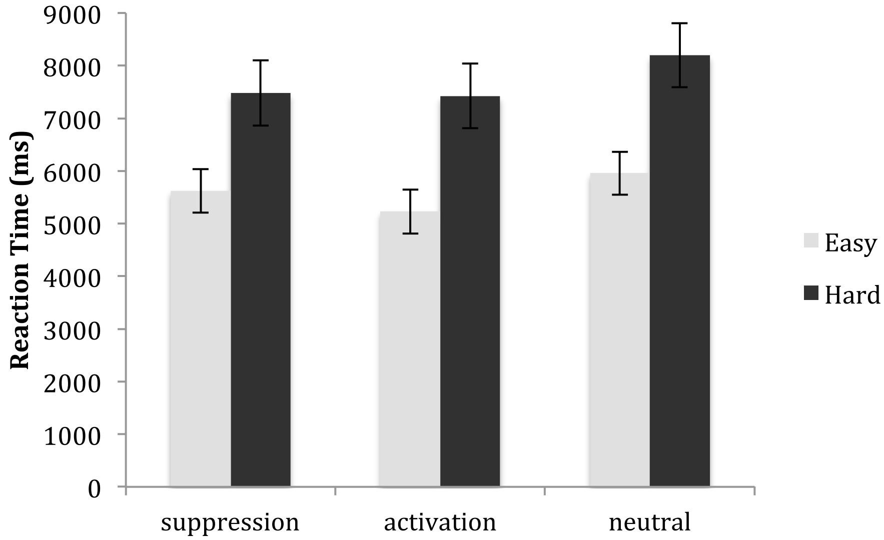

Figure 4. Reaction times on *absent* trial types across *suppression, activation,* and *neutral* conditions for the *easy* and *hard* versions on the visual search task. Error bars are standard errors.

Appendix A

Spontaneous Activity Questionnaire

Instructions: Please answer the following questions about your everyday fidgeting behavior as accurately as you

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1. I fidget:
2. Relative to other people, I feel I fidget:
3. I fidget when I am at home and talking on the phone:
4. I fidget when I am planning ahead for something:
5. I fidget when I am worried about something:
6. I fidget while I read my email:
7. I fidget while I am deep in thought:
8. I fidget while I am reading a book/magazine, or surfing on the Web:

Appendix B

Demographic Sheet

Participant Number____________________

1) Sex (Male, Female): ___________________________

2) Age: ____________

3) Year in College: __________________________

4) Major: _________________________

5) Race: ___________________________

6) Dominant Hand (right, left, both): _____________________

7) Fluent Languages (other than English, if any): _________________________

8) Do you play video games (yes, no): ________________________

If so, what types of games do you play? (first person shooter, strategy, sports, etc):

____

About how many hours per week do you play? ___________________________

9) Do you play sports (yes, no)? _____________________

If so, at what level (intercollegiate, college, town, etc): ______________________

About how many hours per week do you play? _____________________________