The Effect of Cell Phone Use on Frontal Lobe Function

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A thesis presented to the Honors College of Middle Tennessee State University in partial fulfillment of the requirements for graduation from the University Honors College

Fall 2016

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Abstract

There have been many targets of scrutiny regarding the negative effects cell phones can have on people, including: effect of radiation, effect on reading speed, effect on driving, effect on communication, and other similar topics. Not many researchers have looked at the effect the common use for cell phones has on the *brain*. The premise of this study is to establish that the right frontal lobe is not being used when cell phones are utilized for texting, and that this disuse is causing negative effects to right frontal lobe function. To assess the effect that this has on right frontal lobe function and to establish double dissociation, measures of right frontal lobe fluency (RUFF and Spatial Span) and left frontal lobe fluency (COWAT and Digit Span) were given. A Go-No-Go test was also given to test for response inhibition. The Beck Depression Inventory was administered to account for interference by individuals experiencing symptoms of depression. The individuals were also asked to count the number of text messages sent in the last seventy-two hours. The results indicated, consistent with the hypothesis, lower results on the tests of right frontal lobe functioning in individuals with higher rates of text messaging and no change in left frontal lobe functioning. This indicates that cell phone use causes decreased functionality and potential shrinkage of the right frontal lobes, leading to impairment and potential dysfunction in those who subject themselves to excessive amounts of text messaging.

Acknowledgments

First I'd like to thank Dr. Paul Foster for working with me and giving me this great opportunity, and the honors college for being supportive and always helpful when problems arose. I'd also like to thank Conrad Landis for helping gather data, and to my family who listened to the brainstorming about this project for months.

The Effect of Cell Phone Use on Frontal Lobe Function

Introduction

The concern over cell phone use and the potential problems they cause is not a new discussion. It has been on the minds of many since cell phones became commonplace a decade ago. An estimated two-thirds of the American population is in possession of a cell phone (Smith, 2015). There have been considerations that cell phone radiation could cause cancer, a topic that has been addressed thoroughly ("CDC FAQ About Cell Phones," 2014). The possibility that cell phone use may cause cancer has been investigated extensively, mostly with the consensus that the radiation of cell phones does not mutate DNA. However, cell phone use may have deleterious effects in other ways. The possibility exists that text messaging could have alternative deleterious effects on the right frontal lobes, which is a concern that has not been investigated. Two-thirds of the population, a good proportion of which is composed of adolescents between the ages of 18-25, are proud owners of cell phones (Smith, 2015). Adolescents, whose frontal lobes are still developing and who spend much of their time receiving and sending text messages, may be putting their brain functions at risk by using their cell phones. This same age group is sending the highest number of text messages per day, averaging 130 messages a day and almost 4,000 per month (Lupis 2013).

Text messaging is an easy, quick form of communication. However, texting is primarily a verbal form of communicating and therefore does not include some other important aspects of communication. As a primarily verbal form of communicating, texting does not include the prosody, melody, or intonation that is used in expressive speech. This lack of expressional aspects of communication, i.e. the lack of non-propositional aspects of communication, could potentially impair brain function. When regions of the brain important for certain behaviors are not being used they can become negatively affected. Specifically, regional brain dysfunction and, in extreme cases, atrophy may occur with these regions becoming less functional due to the lack of use from not engaging in certain behaviors that are associated with those regions of the brain. Similarly, the opposite is true, existing in an intellectually enriched environment and stimulating one's neural processes prevents atrophy and can stimulate further growth in heavily used areas. The presence of a behavior can affect regions of the brain associated with that particular behavior in a positive way, enhancing function and potentially providing extra safeguards or buffers against later invading impairments.

Evidence for the positive effect enriched environments can have on brain functioning may be obtained from studies examining the effects of enriched versus impoverished environments on rat brain development. For instance, Krech and colleagues conducted an experiment to determine whether rats that were raised in an enriched environment developed better problem solving skills than rats that who were raised in an impoverished environment. Rats that were between three and four weeks old spent thirty days in one of the two environments, then another thirty days being pre-trained and tested, and then were sacrificed for study. It was found that the enriched group showed better brain development, thicker and heavier brains, than the impoverished group (Krech, Rosenzweig & Bennet, 1962). Ickes et al. (2000) found that rats raised in an enriched environment had increased brain-derived neurotrophic (neural tissue growth) factor as compared to those raised in impoverished environments. Further, Greenough, Volkmar, and Juraska (1973) reported that rats raised in an enriched environment had significantly more basal dendritic branches as compared to those raised in isolation.

Other investigations have focused on the effects of "enriched" environments in regard to engaging in intellectual activity in humans. Hultsch, Hertzog, Small, and Dixon conducted a study to determine whether maintaining intellectual engagement could aid in buffering against the effects of Alzheimer's, testing if maintaining an enriched environment can combat the degenerative effects of Alzheimer's. Over a span of six years, middle aged adults were tested, and it was determined that maintaining intellectually engaging activities did aid against decline, and poor engagement worsened the outcome of the disease (Hultsh, Hertzog, Small & Dixon, 1999). Hultsh and colleagues suggested that decreases in "activity patterns result in disuse and consequently atrophy of cognitive processes and skills (p. 245). Hultsch confirmed his hypothesis that disuse of certain areas leads to atrophy using the analysis in this study. Three years later, Beth Azar wrote an article in which she concluded a similar concept, that the more cognitively active the participants were less likely they were to develop the symptoms of Alzheimer's (Azar, 2002).

A set of papers by Maguire and colleagues focused on London taxi cab drivers, following the drivers and obtaining structural MRIs. When compared to control subjects, the taxi cab drivers had significantly greater gray matter volume in their left and right hippocampi. The hippocampus is important in spatial memory and because taxi cab drivers do not have set routes they are required to have extensive training and knowledge of streets and locations within their vicinity. Hence, because of their experiences in having to learn and remember streets, i.e. a cognitive map of the area, the hippocampus became larger, much like muscles after extensive exercise (Maguire, Gadian, Johnsrude, Good, Ashburner, Frackowiak & Frith, 2000).

Maguire and colleagues subsequently expanded their findings by comparing bus drivers with taxi cab drivers. The thought was that although bus and taxi cab drivers have similar driving experiences, the bus drivers have set routes and therefore would require less spatial knowledge. The results of these analyses indicated that taxi cab drivers had larger posterior hippocampal regions, and less anterior region with more navigation experience. However, they also had a harder time learning new visuo-spatial information, which indicates that when one uses an area of the brain more than the other, the more extensively used structures size can increase. Increasing size of a particular structure can also outcompete with surrounding areas, hindering the function of those areas left unused even more. The authors concluded that while the taxi drivers may have better retrograde memory, memories that have already formed and been stored in long-term memory, their anterograde, new memories one is trying to commit to long-term storage, is diminished (Maguire, Woollett & Spiers, 2006).

The aforementioned findings suggest that regions of the brain associated with a particular activity will increase in size and function as a result of engaging in that behavioral activity. However, the reverse may also be true, that regions of the brain may atrophy with disuse, making it clear that neglecting a portion of one's brain can have deleterious effects. Disuse can cause the unused area to no longer function properly and possibly to atrophy in severe cases, just as muscles on one's own legs and arms can atrophy with disuse. These research findings and the potential effect of disuse have serious implications for the increase in text messaging. The possibility exists that the increase in text messaging is having deleterious effects on regions of the brain important for communication. Text messaging, as previously mentioned, lacks prosody, melody and intonation, all of which are important aspects of expressive communication. These more nonpropositional aspects of speech (i.e. prosody and emotion) are regulated by the right frontal lobe. Hence, electing to use this simple and common form of communication (i.e. text messaging) is potentially causing negative structural changes to the right frontal lobe, a structure crucial in maintaining functioning of non-verbal fluency and emotional prosody.

Emotional prosody is defined as "the ability to express and recognize emotions through variations of different parameters of human speech," (Besson, Magne & Schon, 2002, p. 406).

Sending text messages lacks prosody. The sender does not have to express pitch, tone, or any other intonations involved in the emotional prosody of normal speech. The uses of ‘Emoticons,’ a set of line drawings of facial expressions, does not serve the same function as prosody in speech. ‘Emoticons’ do not indicate any real life expression one may be making, and many emoticons are sent without any facial expression or prosody in speed of the person sending the message. Unless the user *does* actually smile or speak with emotional overtones while sending a text message including a smiling ‘emoticon,’ the ‘emoticon’ serves no purpose in prosody, and therefore contributes to the disuse of the nonpropositional aspects of expressive speech.

Expressive aprosodia is a neurological disorder characterized by the absence or difficulty expressing prosody in speech and is commonly a consequence of frontal lobe lesions (Elias & Saucier, 2006). In a study looking at aprosodia, a sixteen-year-old girl who had suffered a stroke to her basal ganglia, a deep brain structure, developed expressive aprosodia and had difficulty expressing emotion in her speech or repeating emotions heard by others. While the basal ganglia itself controls motor functions, it is possible the stroke either directly damaged frontal lobe functioning, or indirectly damaged frontal lobe function through impaired communications, as the MRI scans showed considerable damage (Cohen, Riccio & Flannery, 1994). Heilman, Leon and Rosenbak examined a man who had suffered a right medial frontal lobe stoke and was exhibiting affective aprosodia, but was able to compose sentences and answer questions flawlessly (Heilman, Leon, & Rosenbak 2004). The important detail in Heilman’s study was that the stroke was localized in the right frontal lobe. This finding suggested that that right frontal lobe is specifically involved in nonpropositional aspects of expressive speech. Further support for right frontal lobe contributions to expressive prosody and emotion is provided by a case reported by Ghacibeh and Heilman (2003). The patient exhibited a progressive expressive aprosodia and was found to have right frontal cortical atrophy on an MRI. The RUFF figural fluency test is a measure of right frontal lobe functioning (Ruff, Allen, Farrow, Nieman, Wylie 1994). It is shown to be sensitive in detecting right frontal lobe dysfunction utilizing non-verbal methods (Foster, Williamson, & Harrison 2005).

The left frontal lobe, in contrast, is associated with verbal fluency and propositional aspects of expressive speech. Evidence for left frontal lobe involvement in propositional aspects of speech abounds. Expressive aphasia is a neurological disorder characterized by the absence of expressive propositional speech and is commonly associated with left frontal lobe dysfunction (Heilman & Valenstein, 2003). Patients with left frontal lobe strokes often exhibit significantly reduced fluency. For instance, Baldo, Schwartz, Wilkins, and Drinkers (2006), reported marked deficits in patients with left frontal lobe strokes in their performance on a letter fluency task. Studies conducted by Baldo, Shimamura, Delis, Kramer and Kaplan (2001) and Stuss, Alexander, Hamer, Palumbo, Dempster, Bims, Levine and Izukawa (1998) demonstrated the COWAT as a measure of left frontal lobe function.

Given the aforementioned literature review and the relative contributions of the left and right frontal lobes in expressive propositional speech and nonpropositional speech, respectively, the possibility exists that texting may have negative effects on frontal lobe functioning. Further, the brain structure most likely to be affected by text messaging is the right frontal lobe. However, text messaging likely will not affect the left frontal lobes and verbal fluency since this form of communication remains verbal in nature. Based on the aforementioned research, the following hypothesis is proposed: individuals with a higher number of text messages sent will exhibit worse performance on tests of right frontal lobe functioning when compared to individuals who have a lower number of text messages. However, there will be no difference between these groups in their performance on tests of left frontal lobe functioning. It is also expected that upon performing a correlation between the number of text messages sent and the scores on measures of right frontal lobe functioning will be negative; it is hypothesized that when the number of text messages sent per day is high, the frontal lobe functioning scores will be low, and vice versa. A correlation will also be conducted for left frontal lobe functioning versus text messages sent per day, though this relationship will either not be significant or be positive in nature

Methods

Participants

Fifty-one students at MTSU were sampled and consisted of volunteers from the psychology department who were taking undergraduate psychology courses. The experiment was also available on the MTSU psychology site *Sona-Systems,* a portal available to students required to participate in studies for credit in psychology courses A minimum of fifty individuals was the original participant threshold for the study, and data for fifty-one participants was collected. Demographic information showed the sample consisted of twenty-nine females and twenty-two males. The ages of the participants ranged from eighteen to thirty six. Four individuals reported being left handed, and the remaining forty-seven reported being right handed.

Materials

Controlled Oral Word Association Test

The COWAT required the subject to name as many words as possible that begin with a specified letter (F, A, and S) in the span of sixty seconds. These words could not be proper nouns, or stems added on to words previously used, and they could not use numbers to count. The dependent measure is the total number of words generated. The COWAT assesses lexical fluency and is testing verbal fluency, a measure of left frontal lobe fluency.

The Ruff Figural Fluency Test

The RFFT required the subject to connect a serious of dots in as many different patterns as possible within a one-minute time. Each page consisted of thirty-five individual squares containing five dots. The first three pages had the same pattern of dots, interlayed with different distracters, and the fourth and fifth pages consisted of a different pattern than the prior three pages. On each page, the participant was given one minute to complete as many unique patterns in each five dot square. The total number of unique figures drawn was the dependent variable and the score on the test. The RFFT assessed non-verbal fluency and was a measure of right frontal lobe function.

Digit Span

Digit span includes two parts: forward and backwards. Digit span forwards has six pairs of numerical items that are designated an easy task, and four pairs of numerical items that are designated a hard task. These numerical items were orally presented to the subject and then the subject was asked to repeat the numerical items back orally. If the subject failed to repeat back the numerical item correctly twice in the same subset of items, the task was discontinued. The number of test items recalled will be the dependent variable and the score on the test. Digit span backwards requires the subjects to recall a digit sequence in reverse order, opposite to the forward digit span. The number of test items recalled will be the dependent variable and the score on the test. Digit span is thought to assesses verbal attention and working memory and therefore is a measure of left frontal lobe function.

Spatial Span

This test required the subject to view a series of cubes on a board. The experimenter touches a pattern on the raised cubes, and the subject then touches the boxes in the same order in which the experimenter touched them. The number of cubes touched in the pattern increases as the test goes on, and when the subject fails to correctly repeat the pattern twice in a row in a subset, the task is discontinued. The number of correct sequences recalled, and the longest sequence remembered, will be the dependent variable and the score on the test. This test can also be done in reverse, as with the backwards digit span, in which the subjects are required to recall the sequence in which the cubes were touched and repeat it in reverse. As with the forward task, when the subject misses two consecutive tasks in the same subset, the task is discontinued. The number of correct sequences recalled, and the longest sequence remembered, will be the dependent variable and the score on the test. Spatial span is a measure of nonverbal or visuospatial attention and working memory and is therefore a potential measure of right frontal lobe function.

Go-No-Go

The Go-No-Go test involves showing the subject a stimulus, and requiring him or her to perform an action, i.e. press a button or tap a table, only when that stimulus is presented. The subject was instructed to do nothing if any stimulus besides the target stimulus is shown. Target stimulus can be a number of fingers held up, or a color on a screen, and any other number or color is to be ignored. Number of correct actions and false positives will both be recorded to calculate score as the dependent variable. For this study, the stimulus was tapping on the desk. The experimenter would tap the desk once for no action, and twice for the a subject response. The subject response here was to raise their hand. The task was performed twice, once where the subject was asked to raise their left hand if the stimulus was presented, and then again to raise their right hand if the stimulus was presented. The Go-No-Go assesses response inhibition, a measure of right frontal lobe function.

Beck Depression Inventory

The Beck Depression inventory is a 21 question, multiple choice, self-report examination. Each response to a question has a numerical value that is summed together to produce a score for the test. This score was broken into groups of varying levels of depression, from minimal to severe, and is the dependent variable. The Beck Depression inventory served as a test to control the confounding variable of depression and its potential, and non-related to this study, effect on frontal lobe function and text messaging.

Procedure

Upon arriving, the participants were asked to sign a consent form after appropriate information regarding the study was provided. Following that, the individuals were asked to count the text messages sent in the prior seventy-two hour time period. The total number of text messages sent during this period was calculated and used for the purpose of creating low and high texting groups.

Once the prior information had been gathered, the frontal lobe assessments (RFFT, COWAT, Digit Span, Spatial Span, Go-No-Go) and the Beck Depression inventory were administered in a randomized order in order to prevent one test from affecting another test. The individual was then thanked for their participation and adequate records were made for those wishing to earn credit for their classes.

Results

Initial Analyses

A median split based on the total number of text messages sent was used to create groups of low and high texting. Of the fifty-one participants, the data was divided in the middle to determine the breaking point between high texting and low texting. In order to decide where the final participant fell, as there was an odd number for this study, the data was looked at and the last participant went to the group that their text data was closer to, placing the individual in the high text messaging group. The low text message group was comprised of twenty five individuals whose mean and standard deviation of text messages were 57.48 ± 23.40, and the high text message group was comprised of twenty six individuals whose mean and standard deviation of text messages were 290.46 ± 233.85.

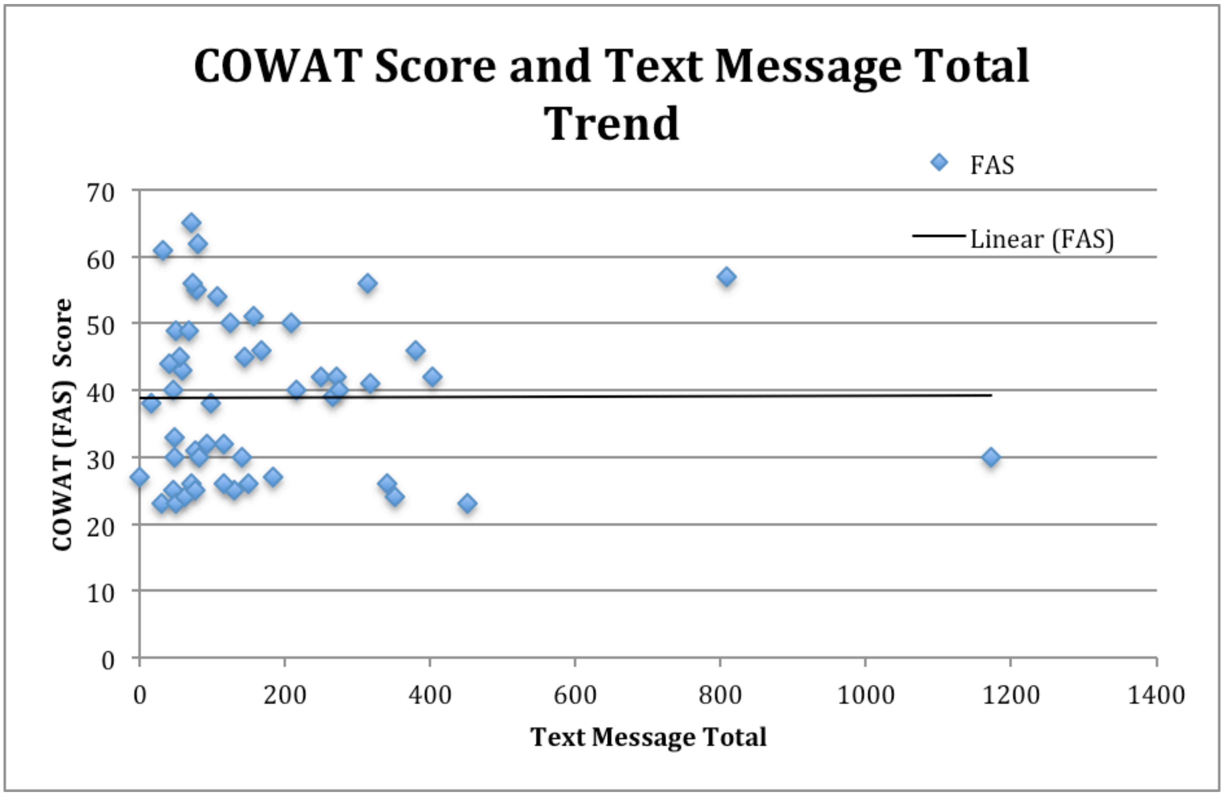
Initial analyses were then conducted to determine group equivalency in regard to depression. The low text message group's Beck-Depression inventory scores had a mean and standard deviation of 9.36 ± 5.46. The high text message group's Beck-Depression inventory scores had a mean and standard deviation of 9.34 ± 7.99. This difference in depression scores was not significant, $F(1)=.000$, $p=.994$.

Primary Analyses

The primary analyses consisted of conducting a series of one-way ANOVAS to determine if group differences existed on any of the measures of frontal lobe functioning. The results of an ANOVA on the RFFT data indicated a significant difference between the low and high texting groups, $F(1)=5.73$, $p=.021$, with the low texting group having a significantly higher score (100.84 ± 19.68) than the high texting group (85.42 ± 25.78). A significant difference was also found between the low and high texting group on the Spatial Span test, $F(1)=4.98$, $p=.030$, with the low texting group having a higher score (17.16 ± 3.23) than the high texting group (15.38 ± 2.40). No group difference were found for the Digit Span test, F(1)=.197, p=.659, or for the COWAT, F(1)=.001, p=.973. Analyses for the Go-No-Go test were not conducted as there was very little variability in the data since the vast majority of the participants performed perfectly on the test.

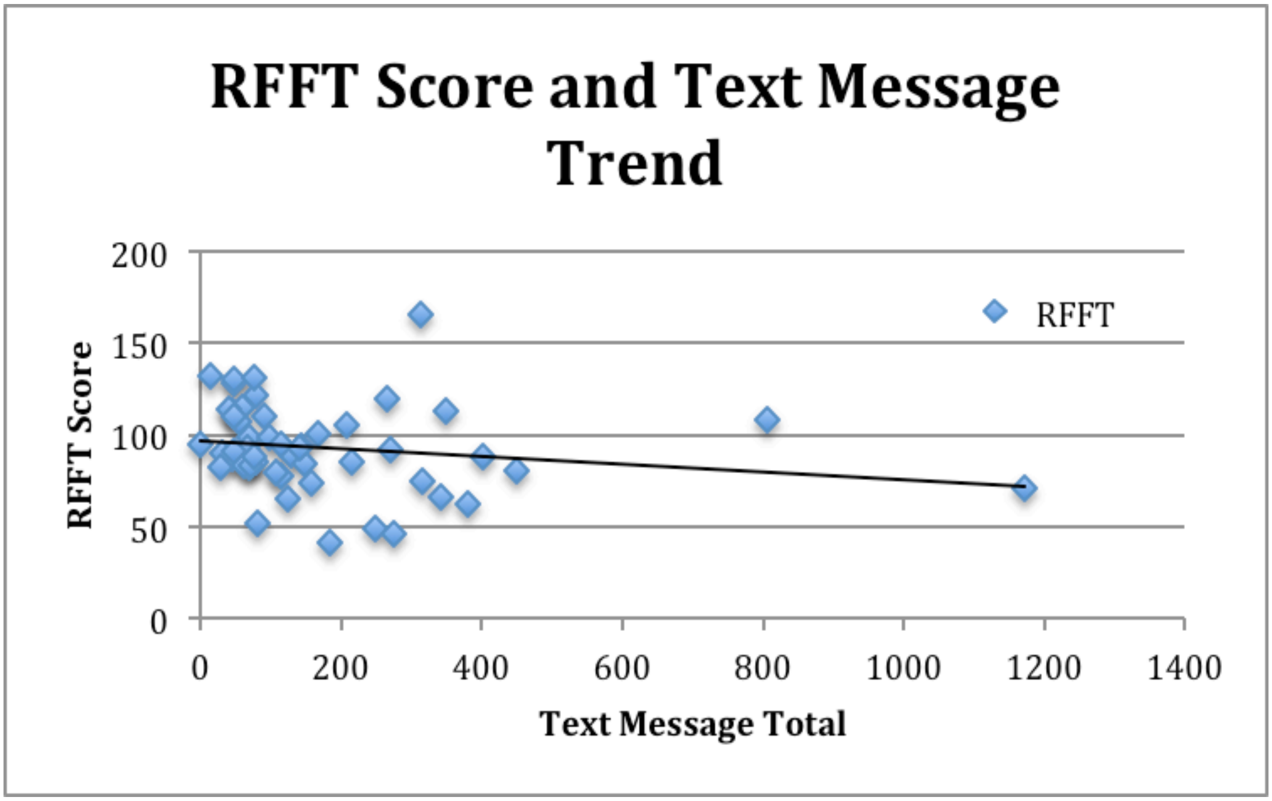
Correlations were then conducted to determine the nature and strength of the relationship between the number of texts and performance on the variables of interest. The results indicated no significant correlation between the number of texts and performance on the COWAT (r = .006, p = .484) or the RFFT (r = -.180, p = .103). Significant correlations were found between the number of texts and Digit Span (r = -.254, p = .036) and Spatial Span (r = -.260, p = .033). Figure 1.1 shows a scatterplot of COWAT scores against text message total as well as a trendline. Figure 1.2 shows a scatterplot of RFFT scores against text message total as well as a trendline. Figure 1.3 shows a scatterplot of Digit Span against text message scores as well as a trendline. Figure 1.4 shows a scatterplot of Spatial Span against text message total as well as a trendline.

Figure 1.1



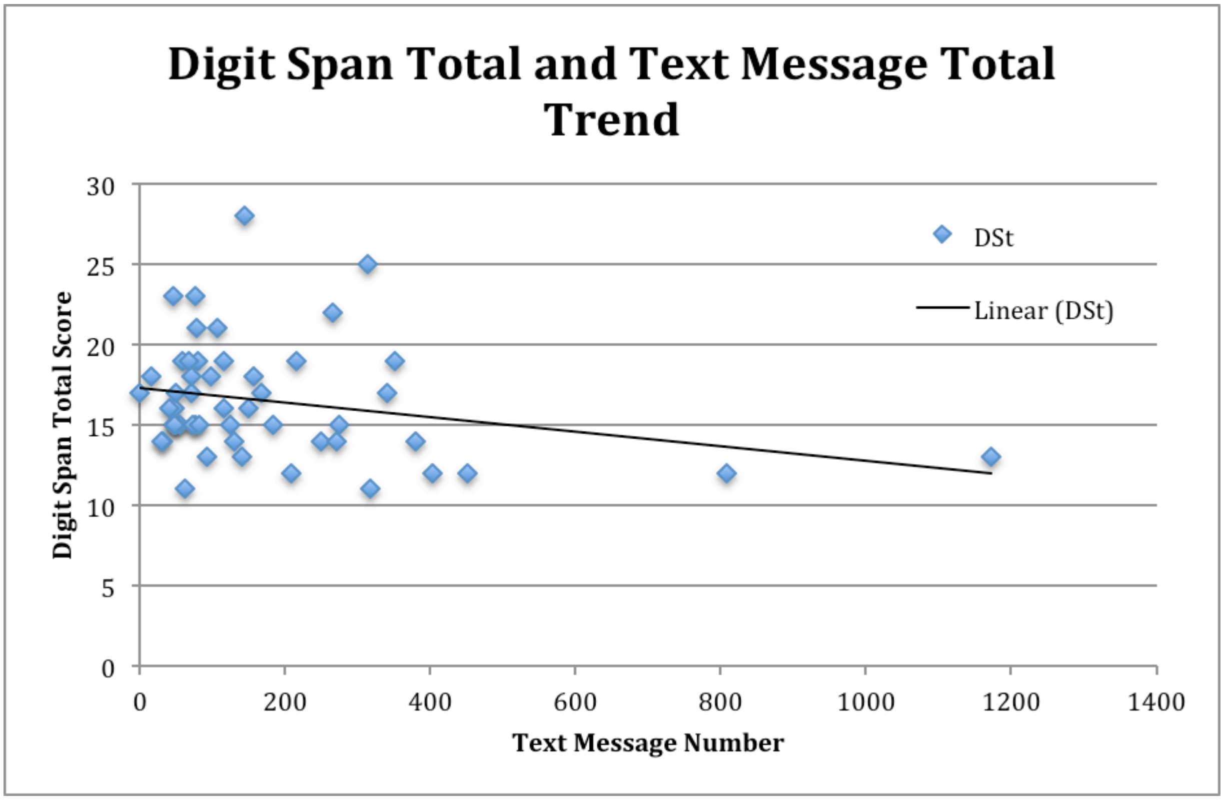
* This figure shows COWAT scores plotted against text message totals as well as a trendline. Note: these two variables did not have a significant correlation (r=.006) when analyzed, and the trendline is almost a flat line.

<u>Figure 1.2</u>



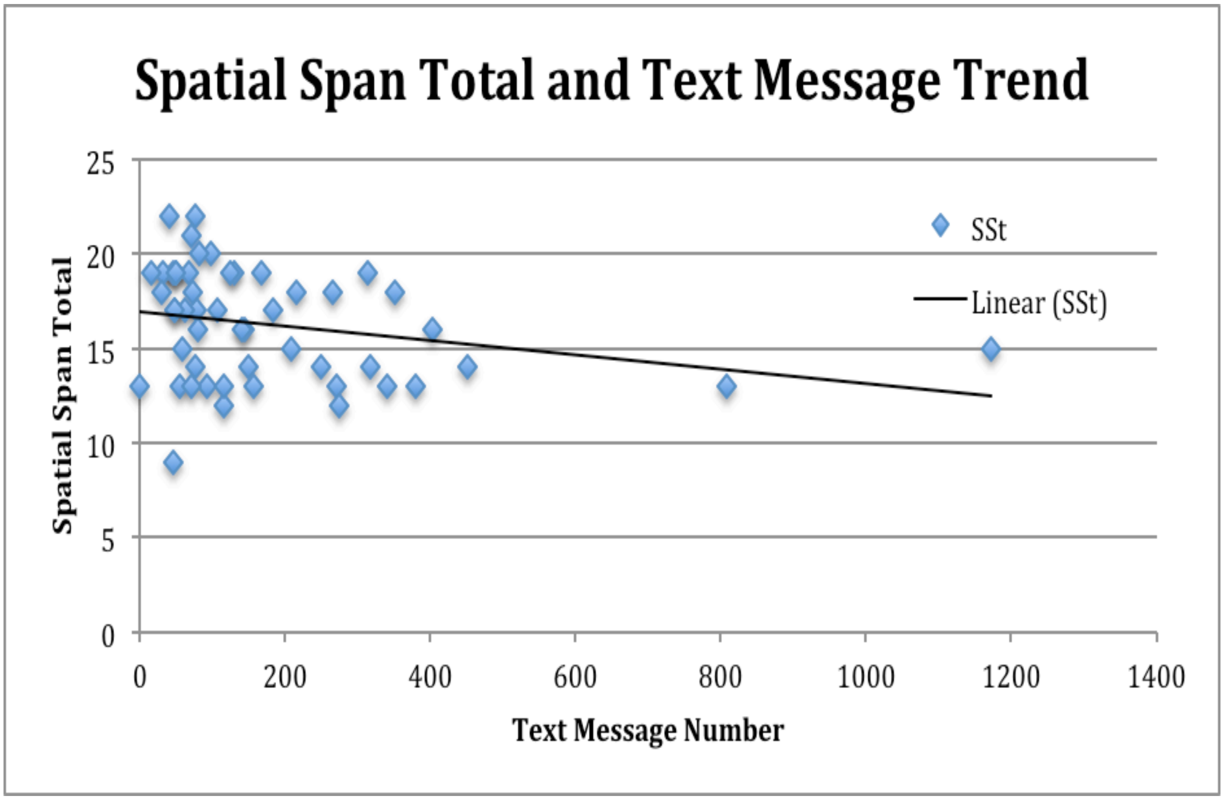
* This figure shows RFFT scores plotted against text message totals as well as a trendline. Note: while the trendline does show a negative slope (as text messages increase RFFT scores decrease) the correlation (r = -.180) was not found to be statistically significant.

Figure 1.3



* This figure shows Digit Span scores plotted against text message totals as well as a trendline. Note: it can be seen there is a negative slope for the trendline (as text messages increase the digit span decreases) and a statistically significant correlation (r = -.254) was found.

Figure 1.4



* This figure shows Spatial Span scores plotted against text message totals as well as the trendline. Note: it can be seen that the trendline has a negative slope (as text messages increase the spatial span score decreases) and a statistically significant correlation (r = -.260) was found between these two variables.

Discussion

The primary hypothesis of this study was that individuals with higher numbers of text messages would exhibit worse performance on measures of right frontal lobe functioning when compared to individuals with lower numbers of text messages. The results of this study support these hypotheses. Specifically, significant differences were found on two indices of right frontal lobe functioning, with lower performance noted for individuals with higher numbers of text messages. There was no difference found between the groups in their performance on tests of left frontal lobe functioning.

Limitations:

One factor not specifically addressed in this study that could also influence the results is the rate of posting on social media sides that are text based, such as *Twitter, Facebook*, and other similar social media sites that may resemble text messaging but are not being accounted for. The study still had several serious implications: increased text messaging diminishes right frontal lobe function. However, there is also the caveat that perhaps the study delves too far to the extremes, and while it may turn out that this is only true in individuals who choose to almost exclusively text message and shut out face-to-face interaction are suffering right frontal lobe deficits, it may not be seen in the average population.

A limitation of this study is that we did not measure face-to-face interactions. This study only looked at the amount of text messages sent. It did not include instant messaging or message board discussion, and it did not look at the possible relationship between text messaging and participant levels of face-to-face interaction. Therefore, we are unable to determine if there is a trade off between the two, if increased text messaging yields decreased face-to-face interaction, which is something that should be addressed, and may yield further important foundations for this division of research.

There may also be a problem with individuals using gaming communications and chat rooms, increasing the amount of time they do not use face-to-face interaction, but will conflict with data due to the text numbers being low, but the frontal lobe deficit being higher due to these outside messaging platforms not taken into account. However, the purpose of the study *is* to single out text messaging, but those individuals could have warped the data in unaccounted for ways.

There is also the fact that this was a quasi-experiment; therefore cause and effect cannot be directly determined. Future research should expand on these findings in a true experimental setting and investigate the relationship further, in ways this study could not.

Ideally, it would have been preferable to be able to perform true randomization, expand the demographic, and get imaging of the brains before and after the experiment. If we had the resources and funds, it would have been interesting to do an fMRI (functional MRI) of the brains of each participant, and then place them in groups where they were told either not to text or to text a lot, of course “a lot” would have to be operationally defined and explored, have them perform with these behaviors for thirty days, longer if possible, and then do another fMRI at the end of the study along with the measures we were able to conduct, and analyze the effects that way. It would have given more concrete conclusions and controlled for some of the potential confounding variables. Perhaps someone later can perform an experiment more in that direction.

Demographic limitations:

There is also the possibility that the MTSU students would only encompass the highs or lows of the spectrum, there will not be many who do not text at all, or who do nothing but text due to confounding variables like busy schedules, excess classes and work loads, class-time assimilation teachers require, etc. Also, the sample was very limited, being only college students, and mostly from the psychology program. The age and location factors would serve to reduce the external validity. It is also possible that the students encompass the absolute extremes, bordering neglect of face-to-face social interaction in favor of text messaging.

Implications:

Dimitrov and colleagues conducted a notable study delving into localized inhibitory attention control in the frontal lobes using a combination of dementia and stroke victim groups and conducting attentional control tasks. Upon analysis of these tasks, the researches noticed slower response times in those who had suffered damage to their frontal lobes (Dimitrov et. al., 2003). It is important also that they noted that the frontal lobes alone are not responsible for all response inhibition, and that some of that complex process is likely to come from the basal ganglia as well. Moreover, this study indicates that frontal lobe damage may cause some problems with response inhibition, but that it is within reason for it to still function, but not to its fullest extent. This is not surprising considering how intertwined many processes in the brain can be; however, frontal lobes play at least some part in inhibition. It is inclinatory that some aspect of response inhibition dysfunction will occur as the frontal lobe dysfunction takes place, though it may only be seen in more severe cases of frontal lobe dysfunction that may not be seen in the sample utilized in this study.

The right frontal lobes are involved in a lot of neurological processes, all of which could be compromised based on the results of this study. If the right frontal lobe functioning is diminished, which this study implicates is occurring when individuals text, every function of the right frontal lobe may be diminished.

Studies by Comer, Harrison and Harrison (2015), Mitchel and Harrison (2010) and Williamson and Harrison (2003) demonstrated that right frontal lobe dysfunction can lead to an inability to control anger and aggression; stress in tangent with dysfunction in the right frontal lobe can further the inability to control negative emotions. Disregard for others as well as another account of increased aggression was found following right frontal lobe trauma (Blair, Cipolotti 2000). Harmon-Jones and Sieglman (2001) and Keune, Van de Heides, Varkuti, Konicar and Birbaumer (2012) showed decreased right frontal lobe function led to increases in anger and aggression. It was also found that individuals with lower right frontal lobe activity experienced lowered inhibitions (Aron, Robbins and Doldreck 2004). Starkstein and Robinson (1997) expanded problems related to poor right frontal lobe functioning to socially inappropriate behaviors as wells as disinhibition. Kirshner saw similar behavioral problems (2014) in dementia patients.

Harrison (2015) determined that Alzherimer's patients with right hemisphere degeneration increases the likelihood of developing behavioral problems related to emotional deficits, aggression and disruptive and socially unacceptable behaviors. Demaree and Harrison created a model linking hostility and violence to right frontal lobe dysfunction (1997). These are the consequences individuals who text may be facing; aggression, violence, hostility, poor inhibition, social disruptiveness and behavioral problems.

It is not uncommon knowledge that frontal lobe development continues on into an individual's twenties, and that development of the frontal lobes during adolescence is crucial. Paus et al. looked at the brains of children in magnetic imaging and determined that as age increased, so did the density of white matter (Paus et al., 1999). The brain continues to develop after birth; it myelinates, allowing for faster pathways, communications and flow for successful maturation of brain functions. The most used pathways continue to thicken and develop even later into life than lesser-used aspects of the brain. If individuals are hindering their frontal lobe function, and at these crucial development ages, they are not only losing some performance and function they had, but potentially limiting what they can still gain. The authors, Paus et al., note that the variations in white matter structure among individuals, the way the white matter forms during development, could even become an indicator in treatments of abnormal function. One big aspect of aging is the degeneration of myelin, which does not reform, leading to slower cognitive processes. Demyelination coupled with plaques in the brain matter constitutes a good portion of the detrimental effects of Alzheimer's, and should these detrimental habits continue, individuals who develop Alzheimer's could be in for a dismal prognosis, with their frontal lobe functioning already having been decreasing for years due to improper upkeep.

The implications of this study are many (disinhibition, impulse control, inappropriate social behavior, slower response times, poorer prognosis for degenerative diseases like Alzheimer's, decreased control over negative emotions, increased hostility and violence, issues following social cues, callous disregard for other, slower cognitive function, social disruptiveness and more). This needs to be known, particularly in a society that is putting phones into younger and younger hands, and more undeveloped brains. Certainly, further research should be conducted and caveats accounted for.

Conclusions and Future Research

Additional research may want to delve into the relationship between talking and texting, whether there may be a negative correlation, and general investigation into the nature of that relationship. It would also be prudent to expand the sample beyond young adult college students, and onto a more variable sample, it may also be beneficial to account for other systems similar to texting (e.g. *twitter,* instant messaging, etc) in future studies for thoroughness. It would also be imperative to develop a study conducted as a true experiment, while taking these other aspects into consideration.

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