International Journal of
EXERCISE SCIENCE

Original Research

The Impact of Cell Phone Texting During Aerobic Exercise On Measures Of Cognition

MICHAEL J. REBOLD‡1, MALLORY S. KOBAK‡1,2, CODY A. CROALL†3, EMILY A. CUMBERLEDGE†3, MATTHEW T. DIRLAM†3, and TIMOTHY P. SHEEHAN†3

[1]Department of Integrative Exercise Science, Hiram College, Hiram, OH, USA; [2]Department of Sport Science and Wellness, The University of Akron, Akron, OH, USA; [3]Department of Exercise Science, Bloomsburg University of Pennsylvania, Bloomsburg, PA, USA

*†denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 12(5): 646-656, 2019. This study assessed the effect of cell phone texting during a 30-minute bout of cycle ergometer exercise on measures of cognition (i.e., reaction time and accuracy). Twenty-eight college students participated in two conditions (*cell phone* and *no cell phone*). Reaction time and accuracy were assessed pre- and post-exercise with the use of the Stroop test. Reaction time was significantly worse ($p < 0.001$) in the *cell phone* condition from pre- (1003.75 ± 178.04 ms) to post-exercise (1124.46 ± 238.55 ms). Reaction time was significantly better ($p < 0.001$) in the *no cell phone* condition from pre- (1107.71 ± 229.54 ms) to post-exercise (953.86 ± 177.42 ms). Accuracy was significantly worse ($p = 0.01$) in the *cell phone* condition from pre- (97.61 ± 2.32) to post-exercise (94.04 ± 7.88). Accuracy was significantly better ($p < 0.001$) in the *no cell phone* condition from pre- (94.82 ± 4.42) to post-exercise (97.39 ± 2.42). In conclusion, using your cell phone for texting can interfere with the cognitive benefits associated with reaction time and accuracy that are developed from participating in aerobic exercise.

KEY WORDS: Reaction time, accuracy, Stroop test, mobile phone, text messaging

INTRODUCTION

Cognition is the mental process of acquiring knowledge and understanding through thought, experience, and the senses (26). Furthermore, cognition can be classified as having three major cognitive domains: 1. Executive function, which includes cognitive abilities such as working memory, reasoning, task flexibility, problem solving, planning, and execution that enable individuals to successfully engage in independent goal-directed behaviors; 2. Memory, which is the process of retrieving stored information; and 3. Attention, which is the ability to selectively concentrate on one aspect of the environment while ignoring other things (25, 26). Cognition has been investigated extensively, but little is known how measures of cognition (i.e., reaction time and accuracy) may be affected during aerobic exercise while simultaneously using a cell phone for texting purposes.

It is broadly known that performing aerobic exercise is associated with improved cognitive functioning (10, 16). Cognitive functioning improvements have been shown to be the greatest in cognitive processes that involve working memory, switching between tasks, and inhibiting irrelevant information (10, 16). Physiological mechanisms, such as increased cerebral blood flow and oxygen transport, alterations in brain neurotransmitters and their functions (e.g., improved release of dopamine and norepinephrine), and morphological changes (e.g., neuronal structure and dendrite branching resulting in the maintenance of brain tissue volume) in the central nervous system have been associated with performing aerobic exercise, and can help explain the improvements that have been observed in cognitive functioning (11, 25). However, there has been much debate as to which modes of aerobic exercise are associated with improvements in cognitive functioning. A number of investigations examining different modes of aerobic exercise (e.g., maximal, submaximal/steady-state, and progressive) and its effects on cognitive functioning have been conducted (4, 5, 9, 13, 15, 24). Due to the robust number of investigations that have examined the effects of aerobic exercise on cognitive functioning, we limited out literature review to those studies that have only examined cycle ergometer exercise because this is the mode of aerobic exercise that our investigation implemented.

Bard and Fleury (5) conducted a study that required participants to cycle to voluntary exhaustion. The participants pedaled continuously for six-minutes at 150-watts, three-minutes at 200-watts, and against resistive loads that increased by 25-watts every minute until exhaustion. Bard and Fleury (5) concluded that intense cycling at maximal intensities had no effect on the participant's performance of a spatial location test. However, when shifting our focus to submaximal/steady-state aerobic exercise many researchers have observed improvements in cognitive functioning (4, 13, 15). Arcelin and colleagues (4) conducted a study that examined cycling at 60% VO_{2max} and concluded that steady-state cycling primarily influenced the response-preparation stage of processing, which was determined by having the participants complete a choice-reaction time test. Similarly, investigations conducted by Fleury and colleagues (13) and Hogervost and colleagues (15) have found submaximal aerobic exercise that is performed for durations anywhere between 20-60-minutes to be the most appropriate for improving multiple cognitive processes. Finally, when reviewing investigations that have implemented an inverted-U function type of exercise bout (i.e., transition from low- to moderate- to high-intensity exercise; progressive exercise protocol), consistent findings have been observed. Salmela and Ndoye (24) examined a progressive cycling bout of exercise and reported that the participant's cognitive performance followed an inverted-U shaped function, with reaction time being faster when heart rate was at 115 beats·min^{-1} as compared to heart rate while at rest or at 145 beats·min^{-1}. Brisswalter and colleagues (9) reported similar findings as Salmela and Ndoye (24), with reaction time following an inverted-U shaped function. The fastest reaction times were observed at mid-range pedaling rates (50 rev·min^{-1}) and slower reaction times at the highest pedaling rate (80 rev·min^{-1}) (9). In summary, majority of the investigations conducted that have examined different modes of aerobic exercise and its effects on cognitive functioning have observed that participants' speed of responding and speed of decision making were improved to a greater extent when the demands of aerobic exercise were increased, but only to a certain extent (i.e., inverted-U shaped function; progressive exercise protocol), as when compared to other modes of aerobic exercise such as maximal and submaximal/steady-state (1, 2, 3, 9, 17, 18, 24). However, it still remains unclear how dual-tasking during aerobic exercise influences cognitive functioning since none of these above mentioned studies have utilized such a protocol.

Due to the cell phone's inherent portability, users can now engage in communicating via texting nearly anywhere and at any time. Research has found that the cell phone is commonly used for texting during work, in the classroom, while watching movies and sporting events, during meals, and while going to the bathroom (14). The concern is that frequent cell phone use may become a distraction and negatively affect performance on other tasks, especially exercise. Findings from recent studies conducted by Rebold and colleagues (22, 23) demonstrated that using a cell phone for texting during treadmill exercise significantly reduces the workload (i.e., average speed) (22), and causes greater participation in low-intensity exercise and less participation in vigorous-intensity exercise (23). This is concerning because according to the American College of Sports Medicine (ACSM), healthy individuals should accumulate ≥ 150-min·week^{-1} of moderate intensity (40-<60% heart rate reserve) exercise, or ≥75- min·week^{-1} of vigorous intensity (60-<90% heart rate reserve) exercise, or a combination of moderate and vigorous exercise to avoid poor health and the early onset on chronic diseases (e.g., heart disease, diabetes) (29). In addition, Rebold and colleagues (21) also demonstrated that using a cell phone for texting can disrupt postural stability by requiring divided attention between dual tasks, and therefore, possibly predispose individuals to greater inherent risks such as falls and musculoskeletal injuries while engaging in activities that require both static and dynamic balance (21).

Cell phone texting has been shown in several recent investigations to have a negative impact on exercise and balance performance (21, 22, 23). However, to the best of our knowledge there is no research that has investigated the effects cell phone texting during aerobic exercise on measures of cognition. Therefore, the purpose of this study was to assess the effects of cell phone texting during a bout of 30-minutes of cycle ergometer exercise on measures of cognition (i.e., reaction time and accuracy). This study utilized a within-subjects design to compare cognitive measure scores (i.e., reaction time and accuracy) during two conditions (*cell phone*, *no cell phone*). It was hypothesized that texting during 30-minutes of cycle ergometer exercise would blunt measures of cognition (i.e., reaction time and accuracy) that are developed from performing aerobic exercise (10, 11, 16, 25) and result in worse reaction time and accuracy scores relative to the *no cell phone* condition.

METHODS

Participants

Twenty-eight college students (n = 15 males, n = 13 females, age 21.61 ± 3.02 years, Table 1) each participated in two, separate, 30-minute exercise conditions (*cell phone*, *no cell phone*) on a cycle ergometer on separate days. A power analysis conducted with G*Power 3.1 (Universitat Kiel, Germany) revealed that 28 participants were needed for a power of 0.80, with an effect size of 1.0, and an □ = 0.05. The order of the two conditions was randomized and each participant completed both conditions (i.e., within-subjects design). Participants were excluded if they did not own a cell phone or if they had a cell phone without the capabilities of sending and receiving text messages, if they had any contraindications to exercise (i.e., orthopedic injuries to the lower extremities), and if they were diagnosed with color blindness as this would affect their ability to distinguish colors during the Stroop test. One-week prior to participation in the study participants were instructed on the benefits and risks and to refrain from caffeinated related-substances (e.g., drinks, foods, supplements) at least two-hours prior to their visit, completed medical history forms and a familiarization trial on the cycle ergometer and Stroop test, and signed an informed consent form. This study was approved by the Bloomsburg University of Pennsylvania Review Board.

Table 1. Average height, weight, and age of the participants.

	Males (n = 15)	Females (n = 13)
Height (cm)	161.56±36.66 cm	156.83±29.37 cm
Weight (kg)	84.87±12.01 kg*	63.01±10.46 kg
Age (years)	21.87±2 years	21.31±3.97 years

All data are means ± SD, *males significantly greater than females for weight, $p < 0.05$ for all

Protocol

Participants reported to the Exercise Physiology Laboratory on two separate days. During each visit participants completed one of the two exercise conditions (*cell phone*, *no cell phone*). This was a within-subjects design as each participant completed both exercise conditions, but on separate days. The order in which the conditions were completed were randomized for each participant. Prior to the initiation of each 30-minute exercise condition each participants' heart rate reserve (HHR) was calculated by using the following equation: (heart rate max – heart rate rest) x % intensity (40-<60%) + heart rate rest (29). This was done to ensure that during each exercise condition participant's cycled at a moderate intensity and stayed within that range for the entire 30-minutes. Participants were required to cycle at a moderate intensity because previous research has demonstrated that speed of responding and speed of decision making were improved to a greater extent when the demands of aerobic exercise were increased, but only to a certain extent (i.e., inverted-U shaped function; progressive exercise protocol) (1, 2, 3, 9, 17, 18, 24). In addition, ACSM also states that healthy individuals should accumulate ≥ 150-min·week^{-1} of moderate intensity (40-<60% HRR) exercise, or ≥75-min·week^{-1} of vigorous intensity (60-<90% HRR) exercise, or a combination of moderate and vigorous exercise to avoid poor health and the early onset on chronic diseases (e.g., heart disease, diabetes) (29). Participants were also familiarized with the cycle ergometer (Monark 828E, Langley, WA), and instructed that during both exercise conditions that once research personnel got them to a moderate-intensity based off of their heart rate recordings, the 30-minute exercise session would begin and they would be allowed to alter the speed and/or resistance at any time during the 30-minute session as long as they stayed within their prescribed moderate-intensity heart rate zone. Heart rate was measured continuously throughout both 30-minute exercise conditions (*cell phone*, *no cell phone*) by using a heart rate monitor (Polar, Kempele, Finland).

After each participant's HRR was calculated, and after they were familiarized with the cycle ergometer and exercise condition protocols they were then instructed to complete the Stroop test. The Stroop test was a version provided by ePsych™ an electronic Psychology test (8) that was completed on a desktop computer with a keyboard. During the Stroop test participants were given four blocks of trials (50 trials to a block). On each trial a colored word appeared on the screen. Some of the words were neutral words (e.g., like "water"), while others spelled out the name of a color (e.g., like "red"). Participants were instructed to press the first letter of each color name as quickly as possible. For example, if the word was printed in red, participants were instructed to press the letter "r" on the keyboard. Words were presented in either red, blue, green, yellow, or purple. Participants were provided with instructions on how to complete the Stroop test when they volunteered to participate in this study, and took part in a familiarization trial one-week prior to their first scheduled visit. As soon as each participant completed their pre-Stroop test they then immediately engaged in their 30-minutes of exercise. As soon as the 30-minutes of exercise was completed, participants then immediately completed their post-Stroop test. The same procedures were implemented for both exercise conditions (*cell phone*, *no cell phone*).

During the *cell phone* exercise condition participants were instructed that they could only use their cell phone for texting purposes. In another discrete location within the Exercise Physiology Department research personnel were with one of the participant's friends that were recruited during the informed consent process. Friends of the participants were recruited so that they could text the participants during the *cell phone* condition and to create a more practical experience. Friends were instructed that they could text anything that would simulate a conversation that they would normally have with the participants. If participants did not respond to a text, friends were instructed to wait two-minutes before sending another text and this process continued until participants either responded to the texts or the 30-minutes had elapsed. During the *no cell phone* condition participants did not have access to their cell phone nor any interaction with other individuals or electronics and exercised in a quiet, distraction-free room with only research personnel present for supervision. Research personnel present in the room did not interact with the participant during cycle ergometer exercise.

Statistical Analysis

All data were analyzed with SPSS version 20.0 (SPSS Incorporated, Chicago, IL) with an a-priori α level of ≤ 0.05. Males and females physical characteristics (age, height, weight) were compared using independent samples-t-tests. Because there were no hypotheses based upon sex, it was not included as an independent variable in all subsequent analysis of variance (ANOVA) models. Two condition (*cell phone*, *no cell phone*) repeated-measures ANOVAs were utilized to examine differences in reaction time and accuracy. Post-hoc analyses for all significant main effects were completed using t-tests with the Benjamini and Hochberg False Discovery Rate correction (6).

RESULTS

Independent samples-t-tests revealed significant differences in males and females physical characteristics for weight (Table 1).

There was a significant (F = 10.16, $p < 0.001$) main effect of condition for reaction time. Reaction time was significantly worse ($p < 0.001$) in the *cell phone* condition from pre- (1003.75 ± 178.04 ms) to post-exercise (1124.46 ± 238.55 ms) (12.03% reduction in reaction time from pre- to post-test). Reaction time was significantly better ($p < 0.001$) in the *no cell phone* condition from pre- (1107.71 ± 229.54 ms) to post-exercise (953.86 ± 177.42 ms) (13.89% improvement in reaction time from pre- to post-test).

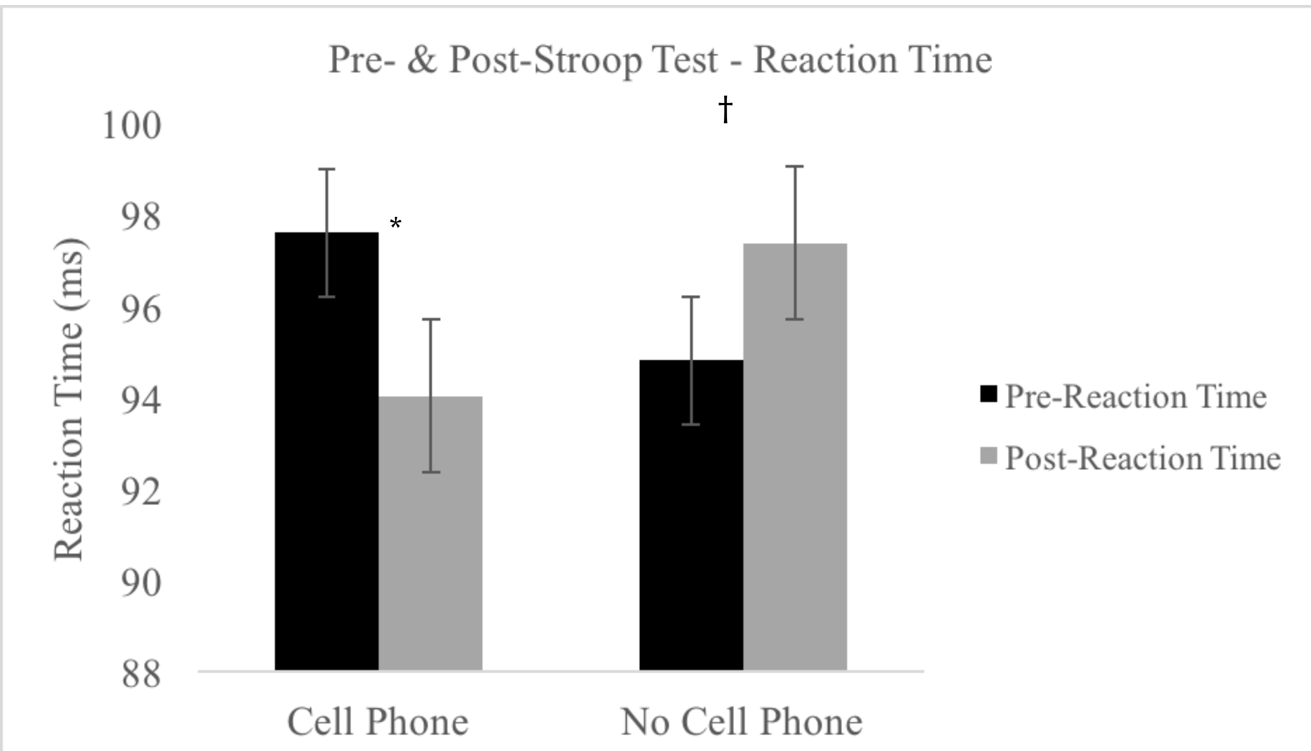

Figure 1. Average reaction time (ms) from pre- to post-Stroop test in the *cell phone* and *no cell phone* conditions. *reaction time was significantly worse ($p < 0.001$) from pre- to post-Stroop test in the *cell phone* condition. †reaction time significantly improved ($p < 0.001$) from pre- to post-Stroop test in the *no cell phone* condition.

There was a significant (F = 4.97, $p = 0.003$) main effect of condition for accuracy. Accuracy was significantly worse ($p = 0.01$) in the *cell phone* condition from pre- (97.61 ± 2.32%) to post-exercise (94.04 ± 7.88%) (3.66% reduction in accuracy from pre- to post-test). Accuracy was significantly better ($p < 0.001$) in the *no cell phone* condition from pre- (94.82 ± 4.42%) to post-exercise (97.39 ± 2.42%) (2.71% improvement in accuracy from pre- to post-test).

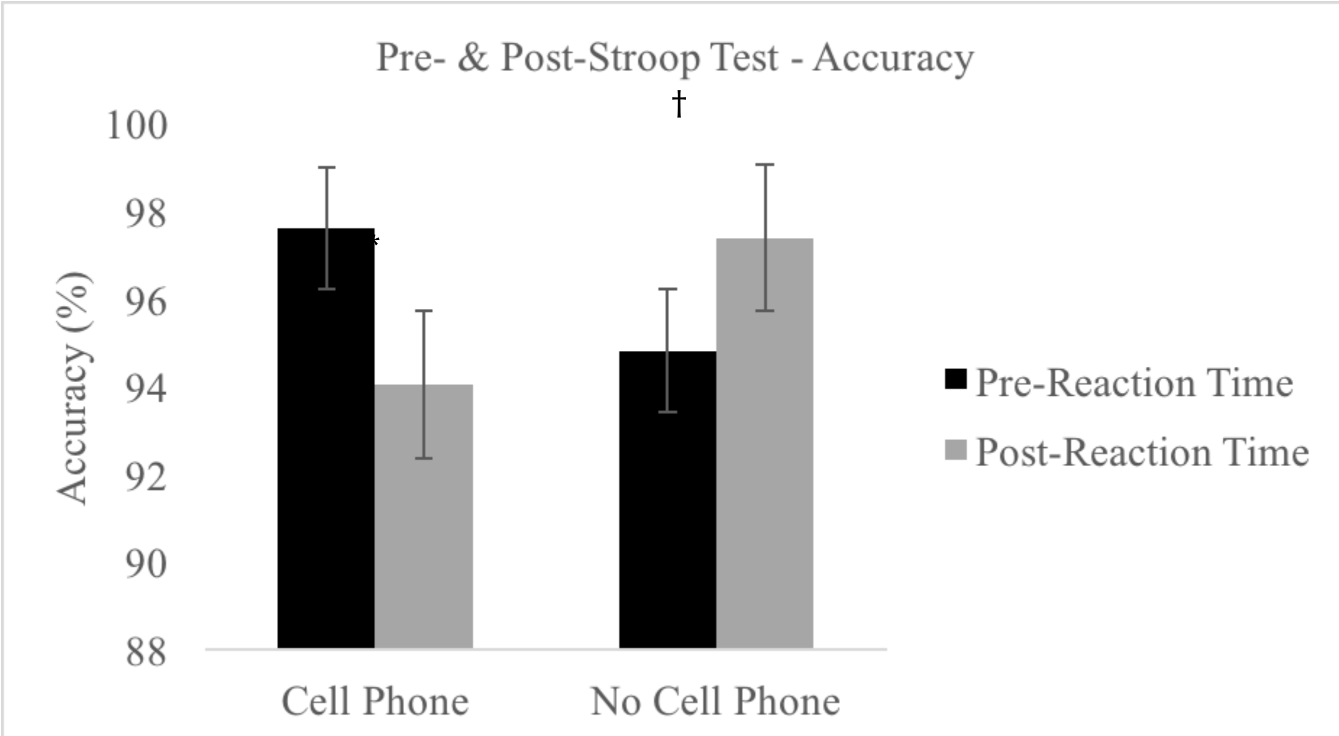

Figure 2. Average accuracy from pre- to post-Stroop test in the *cell phone* and *no cell phone* conditions. *accuracy was significantly worse (p = 0.01) from pre- to post-Stroop test in the *cell phone* condition. †accuracy significantly improved (p < 0.001) from pre- to post-Stroop test in the *no cell phone* condition.

DISCUSSION

This study utilized a within-subjects design to analyze how cell phone use (i.e., texting) during 30-minutes of cycle ergometer exercise would affect measures of reaction time and accuracy. There have been a robust number of investigations that have observed improvements in measures of cognitive functioning after performing aerobic exercise (4, 5, 9, 10, 13, 15, 16, 24). However, there is no existing research that has examined how cell phone use (i.e., texting) during aerobic exercise affects measures of cognition. Previous studies that have examined cell phone use during exercise have all concluded that cell phone use during exercise creates a possible distraction effect that negatively impacts health, fitness, exercise intensity, and balance (21, 22, 23). According to Neider and colleagues (20), the phenomenon that explains a decrease in performance is known as the dual-task effect, which is when individuals simultaneously divide their attention between dual tasks and neither task receives the attentional resources it would have if it were attempted alone (20). Our findings are consistent with these previously mentioned studies, with measures of cognition (i.e., reaction time and accuracy) being improved from pre- to post-Stroop test without the use of a cell phone, and these measures being negatively affected when simultaneously engaging in aerobic exercise while using a cell phone for texting purposes.

The present results from the *cell phone* condition are consistent with what was hypothesized and are in agreement with previous studies, which have identified cell phone texting to negatively affect health, fitness, exercise intensity, and balance (21, 22, 23). It was observed from pre- to post-Stroop test that measures of cognition (i.e., reaction time and accuracy) were both negatively affected when using the cell phone for texting purposes during the 30-minutes of cycle ergometer aerobic exercise. One mechanism that can help explain this observation can be possibly attributed to mental fatigue. Mental fatigue has been referred to as the effects one experiences, such as difficulties in concentrating and focusing attention, that occurs after or during prolonged periods of cognitive activity (7). It is possible that the dual-task (i.e., 30-minutes of cycle ergometer aerobic exercise plus cell phone texting) induced some level of mental fatigue. Boksem and colleagues (7) also stated that those that become mentally fatigued have the inability to allocate their attention effectively, which is something that was required of our participants when completing the Stroop-test. Future studies should consider implementing the use of questionnaires such as the Profile of Mood State (POMS) (19) or Brunel Mood Scale (BRUMS) (27) to assess mood.

In contrast, the present results from the *no cell phone* condition are also consistent with what was hypothesized and are in-line with earlier studies, which have suggested and identified that performing aerobic exercise to be associated with improved cognitive functioning (4, 5, 9, 10, 13, 15, 16, 24). This was expected because participants were not engaging in a dual-task during this condition, and those previously mentioned studies observed improvements in their participant's cognitive functioning after performing aerobic exercise with no dual-tasking (4, 5, 9, 10, 13, 15, 16, 24). If participants were engaging in a dual-task like which was required of them in the *cell phone* condition, they would be required to simultaneously divide their attention and therefore, possibly have some level of mental fatigue induced, and possibly not benefit fully from the physiological benefits (e.g., increased cerebral blood flow and oxygen transport, alterations in brain neurotransmitters and their functions, and morphological changes in the central nervous system) that are developed from participating in aerobic exercise (11, 25). An important aerobic exercise variable to take into consideration is aerobic exercise intensity. This is important to take into consideration because previous research has indicated that high-intensity exercise induces both mental and physical fatigue (12, 28). In addition, improvements in cognitive functioning have been observed when participants engaged in submaximal/steady-state (60% VO_{2max}) cycle ergometer aerobic exercise lasting anywhere between 20-60 minutes (4, 9, 13, 15), and in aerobic exercise in which the demands of the exercise are increased, but only to a certain extent (i.e., inverted-U shaped function; progressive exercise protocol) (1, 2, 3, 9, 17, 18, 24). In the current study participants were required to cycle at a moderate intensity (40-<60% HRR) for 30-minutes to reduce both mental and physical fatigue.

While this current study yields novel and useful information, it is not without limitations. In the present study we only examined cycle ergometer exercise, which may not be the mode of exercise all participants preferred, thereby limiting our ability to generalize our findings to other modes of aerobic exercise. By requiring participants to complete 30-minutes of exercise on the cycle ergometer may have affected their mood state, therefore, possibly affecting the Stroop-test results post-exercise. Another potential limitation of the present study may be related to the *cell phone* condition and explaining to the participants that they were only allowed to use their cell phone for texting purposes only. The participants may have had speculations of the purpose of the study after having this explained to them. Another potential limitation in regards to the *cell phone* condition may have been the recruitment of the participant's friends. When recruiting the participant's friends there was no way to account for if the friends had disclosed any information about the study to the participants. If friends of the participants disclosed any information about the study, then this may have affected how often the participants responded to texts that they received. In addition, another potential limitation in regards to the *cell phone* condition was that we did not record any information about the texting conversations (e.g., how many texts received, how many texts responded to, one-word responses, etc.). As stated previously, texting conversations were not recorded or viewed by the research personnel as we initially deemed this not to be of importance to the primary purpose of our study. However, recording some information as it relates to texting conversations could have provided additional insight as it pertains to the findings of the study. For example, one-worded responses may have not induced as much mental fatigue as someone who is putting more thought/effort into their responses. The sample also consisted of only college-aged students which have been raised entirely in the digital age, while other populations (middle-aged and older adults) may have differing results due to the possibility of having less experience and comfort associated with digital technology, thus limiting our ability to generalize these results to other populations. Lastly, we did not utilize the use of any questionnaires to assess mood state (POMS, BRUMS, etc.). Future studies may wish to utilize the use of these questionnaires to obtain information about mood state.

It has been known for years that performing aerobic exercise has been associated with improvements in cognitive functioning (10, 16). This has led to the development of aerobic exercise recommendations for both healthy and special populations because cognition is a mental variable that is needed for the successful engagement in all facets of life. Presently, we have demonstrated that using a cell phone for texting purposes during cycle ergometer aerobic exercise significantly affects measures of cognition (i.e., reaction time and accuracy) in a negative way. Reaction time was significantly worse in the *cell phone* condition from pre- to post-exercise, while on the other hand, reaction time was significantly better in the *no cell phone* condition from pre- to post-exercise. The same can also be said for accuracy. Accuracy was significantly worse in the *cell phone* condition from pre- to post-exercise while it was significantly better in the *no cell phone* condition from pre- to post-exercise. Therefore, in conclusion, using your cell phone for texting purposes can interfere with the cognitive benefits associated with reaction time and accuracy that are developed from participating in aerobic exercise.

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