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Obstacle Avoidance During Texting while Walking: Cognitive Capacity Predicts Performance.

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Obstacle Avoidance During Texting while Walking: Cognitive Capacity Predicts Performance.

by

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Dedication

To the newest member of my family – Aisha (my niece).

In the memory of Maa and Baa.

Acknowledgements

Special thanks to my mentors Dr. Dingwell and Dr. Castelli.

Thanks Mandy and Mary Rose for the help with data collection and thesis edits, JY and Hannah for the help with data analysis. I'd like to thank all of our lab members. This thesis would have not been possible without everyone's support.

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Abstract

Obstacle Avoidance During Texting while Walking: Cognitive Capacity Predicts Performance.

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Introduction: Cell phone related pedestrian injuries have been increasing. The effect of cell phone use on the ability to avoid obstacles has not yet been studied yet. Here, we examined the impact of cell phone use and task complexity on ability to avoid an obstacle. Additionally, we studied the influence of baseline cognitive capacity on performance.

Method: Thirty young adults walked on a treadmill in a virtual reality environment, with and without performing a Cell Phone Task while negotiating No, Simple and Complex objects. Cognitive Capacity was measured using standardized cognitive tests. Cell Phone and Obstacle Negotiation Task performance for different conditions were compared. Linear correlation analysis of Cell Phone and Obstacle Negotiation Task performance with Baseline Cognitive Capacity was conducted.

Result: Percent Collision, Movement Time and Variability in Movement Time increased due to the cell phone use. Movement Time was higher for Complex as compared to Simple Object Negotiation. Cell Phone Task performance was adversely affected due to object negotiation. Individuals with lower PPVT RT and Failure to Maintain Set had less collisions when used cell phone along with avoiding obstacles. Individuals with higher

Flexibility performed better on the Cell Phone Task while negotiating obstacles simultaneously.

Conclusion: Use of a cell phone affects pedestrian safety by compromising with their ability to avoid obstacles. Additionally, an individual’s response depends on their cognitive capacity.

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Chapter 1: Introduction

Emergency room data shows an increase in the number of pedestrian injuries caused due to cell phone use in the United States (Fig. 1). Surprisingly, the number of such injuries were more than 1,500 in 2010 (Nasar, 2013). These numbers do not include injuries treated outside emergency rooms. Thus, the actual number of pedestrian injuries due to cell phone use could be much higher. Despite a high rate of injuries, pedestrians are usually engaged in using a handheld device (e.g. cell phone and music player) for talking, listening to music, reading or performing typing tasks (e.g. texting, playing games, etc.).

Use of a cell phone while walking affects pedestrian safety. When observed at crowded streets, distracted pedestrians took more time to cross an intersection (Hyman, Boss, Wise, McKenzie, & Caggiano, 2010; Thompson, Rivara, Ayyagari, & Ebel, 2013) and were less likely to obey safe street crossing behavior (e.g. following traffic lights, looking both ways before entering an intersection, etc.) (Thompson et al., 2013). Therefore, it is evident that pedestrians' behavior is altered due to cell phone use.

Nevertheless, more than 25% pedestrians were found using a handheld device, at a busy intersection (Basch, Ethan, Rajan, & Basch, 2014; Thompson et al., 2013). Similarly, 43.2% of pedestrians were distracted by a handheld device at an intersection on a University Campus (Nasar, Hecht, & Wener, 2008). Thus, it is evident that a considerable number of people use a handheld device while walking.

There has been an increase in the number of cell phone owners. In the U.S., the number of smart phone users in 2014 was more than 2.5 times than in 2010 ("Smartphone users in the United States 2010-2019," 2015). A large number of people distracted by a cell phone while walking and increasing injuries, have led to an increase in the concern related to pedestrian safety. Authorities have created policies and conducted campaigns, to encourage people to walk without being distracted by a cell phone and other handheld devices (Mwakalonge, Siuhi, & White, 2015), but they have not been able to completely stop pedestrians from using handheld devices.

Literature: Description	Result	What has not been studied
Epidemiology studies: estimated the number of accidents caused due to cell phone use.	Number of cell phone related pedestrian injuries are increasing ("Smartphone users in the United States 2010-2019," 2015)	The underlying cause of such accidents is not known.
Observational studies: observed pedestrian behavior.	People become less aware of their environment while using cell phone (Hyman et al., 2010)	Studies were conducted in an uncontrolled environment. Therefore, the impact of the difference in the number of objects (e.g. obstacles like a car and other people) is not known. They did not study response to obstacles. Biomechanics is not addressed.
Virtual Reality studies: conducted in virtual reality environment.	Talking on cell phone leads to increase in street crossing time (Chaddock, Neider, Voss, Gaspar, & Kramer, 2011)	They did not study the impact of texting. Additionally, they did not address biomechanics.
Biomechanics studies: studied the effect of texting on human biomechanics.	Walking is affected due to texting (Lamberg & Muratori, 2012)	Accidents are caused due to failure to avoid obstacle. However, these studies did not address obstacle avoidance.

Table 1: Brief description of state of literature.

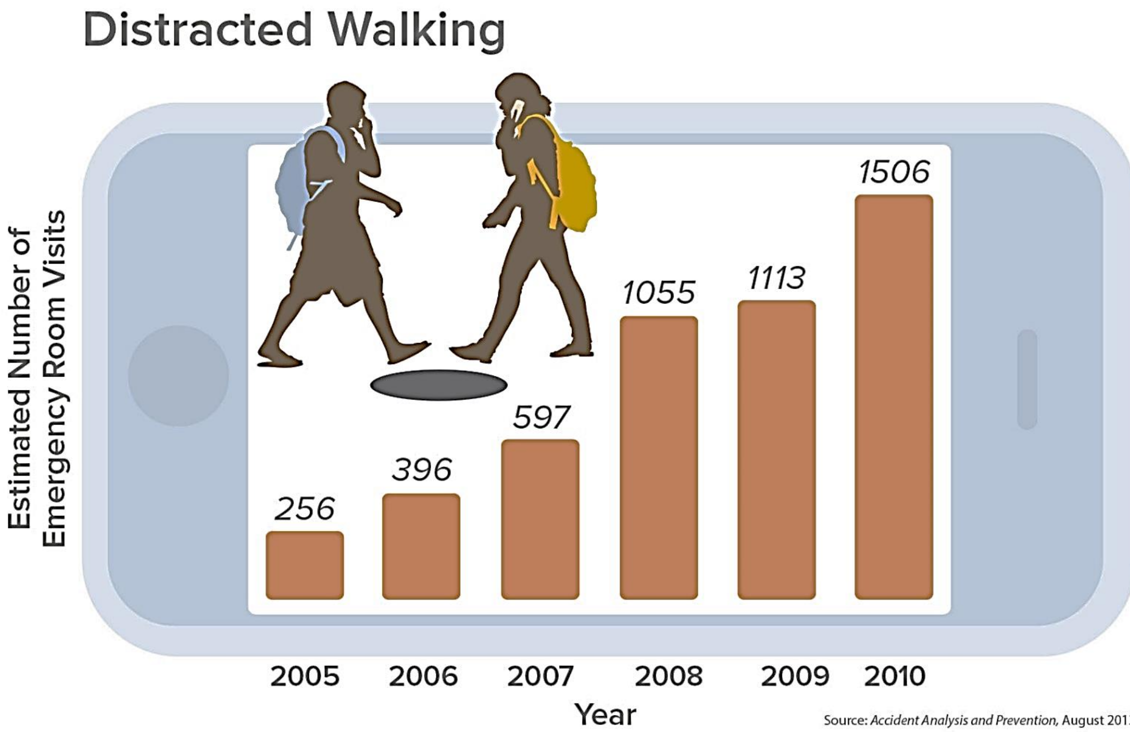


Figure 1: Number of cell phone related pedestrian injuries treated in emergency room in United states ("Distracted Walking: Injuries Soar for Pedestrians on Phones," 2013)

The underlying cause of these cell phone related pedestrian injuries is not known. Therefore, it is critical to study the effects of a cell phone use on pedestrians walking behavior. We studied the influence of a cell phone use on pedestrians' obstacle avoidance behavior. The effects of complexity of the obstacle avoidance task on pedestrians' performance was also examined. Additionally, the impact of the baseline cognitive capacity on individuals' performance was investigated.

Cell phone use by pedestrian induces 'Inattentional blindness' (Hyman et al., 2010), which is defined as a lack of attention leading to failure in perceiving unusual objects in the surrounding. While using cell phone, pedestrians become less aware of objects in their vicinity, like a sign board (Hyman et al., 2010), a clown riding a unicycle (Hyman et al., 2010), money hung on a branch of a tree (Hyman Jr, Sarb, & Wise-Swanson, 2015). These studies have shown that, people are less probable to perceive objects in the environment surrounding their pathway, when they are distracted while walking. However, collisions are caused due to obstacles present on the path, but the effect of cell phone on pedestrians' ability to perceive an obstacle in their path is not known and has not been systematically studied. Additionally, in the above mentioned studies the environment was not tightly controlled (i.e. number of obstacles people, cars etc. was not fixed), which might have affected responses. However, the effect of complexity of the environment or obstacle avoidance is not known (Table 1).

Biomechanical studies conducted in a controlled environment have found that the use of a cell phone by pedestrians affects their walking. Cell phone use leads to reduced walking speed (Cha, Kim, Park, & Song, 2015; Haga et al., 2015; Lamberg & Muratori, 2012; Strubhar et al., 2015), cadence (Cha et al., 2015; Parr, Hass, & Tillman, 2014; Strubhar et al., 2015), stride length (Cha et al., 2015; Demura & Uchiyama, 2009) and step length (Cha et al., 2015; Strubhar et al., 2015). Thus, the alteration in walking behavior due to a cell phone use has been studied. However, these results do not provide sufficient information about the cause of injuries. Pedestrian injuries are generally caused due to collision with an obstacle. Nevertheless pedestrians' response to obstacles while being distracted by a cell phone has not received much attention yet.

Few studies investigated the consequences of a cell phone use on pedestrian's ability to step over obstacles in the environment. These studies found a reduction in gait velocity and stride length due to texting in the presence of small obstacles, which could be stepped over (Demura & Uchiyama, 2009). However, there is no study that has examined response to obstacles which require pedestrians to change their walking path (e.g. car, other people, pole, etc.) instead of walking over.

Studies performed in a virtual reality environment found that undistracted pedestrians take less time to cross a street as compared to those talking on a cell phone (Chaddock, Neider, Lutz, Hillman, & Kramer, 2012; Neider et al., 2011). A recent study looked at the behavior of pedestrians distracted by texting on a tablet mounted on a treadmill (Banducci et al., 2016), but these did not study the effect of texting, which compels individuals to shift their vision from their path to their cell phone.

Walking performance depends on individual's cognitive capacity, such as attention and executive function (Yogev-Seligmann, Hausdorff, & Giladi, 2008). Executive function is comprised of cognitive flexibility, inhibition and working memory (Davidson, Amso, Anderson, & Diamond, 2006; Zelazo, Craik, & Booth, 2004). However, what components of executive function affects individuals' walking performance is partly unclear. A study showed that, individuals with higher processing speed are more successful in crossing a street; something that is important for safety and quality of life (Chaddock et al., 2011). Although, the impact of other cognitive capacity on individual's performance has not been studied. As such, there is both a paucity of research and currently equivocal findings.

Little is known about the effects of a cell phone use on pedestrians' performance. Accordingly, we studied how the ability to negotiate an object is affected due to the use of a cell phone. We hypothesized that pedestrians would take more time and would fail more often, to respond to an object, when using a cell phone. We also expected that, performance on cell phone task would be better in the absence of objects in the environment. Moreover, we wanted to examine how an increase in the complexity of the obstacle avoidance task affects pedestrians' performance. We hypothesized, the cell phone and object negotiation performance would decline due to increase in the complexity of the object negotiation. Furthermore, we hypothesized that individuals with better cognitive capacity will perform better on both cell phone and object negotiation.

Chapter 2: Method

In the methods section of this paper the participants, data collection procedures and analysis are described. University IRB-approved signed informed consent was obtained from individuals before participating.

PARTICIPANTS

Thirty young, healthy participants between ages 18-29 were recruited by word of mouth and by posting flyers (Appendix A) at different locations at the University of Texas at Austin.

Participants included 16 female and 14 male (Table 1). The two sex groups were significantly different in height. However, they were similar in weight, age and Body Mass Index (BMI), (BMI = Body weight (kg) / (Body height (m))^2).

	Male	Female	All	P-Value
# Participants	14	16	30	
Body Mass (kg)	70.92 ± 16.28	61.86 ± 11.39	66.09 ± 14.39	0.086
Height (m)	1.80 ± 0.07	1.63 ± 0.05	1.71 ±0.10	0.000
BMI (kg/m^2)	21.64 ± 3.41	23.30 ± 3.41	22.53 ± 4.19	0.280
Age (yr)	22.07 ± 3.17	21.43 ± 3.94	21.73 ± 3.56	0.635

Table 2: Demographics of the participants. P-values are for 2-sample t-tests with equal variances assumed.

EXPERIMENTAL PROTOCOL

Participants arrived in the Nonlinear Biodynamics Lab (BEL, 530) at the University of Texas at Austin. Each participant was required to come for one, three hour session. Broadly, they were asked to fill out survey forms, perform cognitive tasks and walk on a treadmill with and without using a cell phone, tests were conducted in the order they are mentioned in Checklist (Appendix B). Verbal instructions were provided throughout.

Participants were provided with an informed consent (Appendix C). Participants read the consent form thoroughly and were verbally provided detailed information on what they had to do throughout the experiment. The participants were also given an opportunity to ask questions before signing the consent form. The participant's confidentiality was maintained by assigning a coded participant ID to individuals and using that participant ID for further analysis.

Individuals' were tested for color blindness, they had to identify color of each row of the first column on the color blindness test sheet (Appendix D). All the participants were able to correctly identify the three colors red, green and blue, thus suggesting that none of the participants were color blind.

Following this, KBIT-2 was administered using protocol described by Kaufman and Kaufman (2004), for the purpose of measuring crystallized intelligence. It took an average of 20 minutes to administer this test. The test consists of three sections – verbal knowledge, matrices, and riddles. Each section had multiple questions, which required participants to respond with a word or select one of the multiple pictures. Verbal knowledge and riddles section measured verbal intelligence, whereas non-verbal knowledge was measured by matrices portion of the test.

Participants were asked to fill Health History Questionnaire and Physical Activity survey (Appendix E), Cell Phone Usage Questionnaire (Appendix F) and Handedness Assessment (Appendix G).

The cognitive battery consisted Perceptual Vigilance Task (PPVT), Go/No-Go (GNG) and Berg's Card Sorting Test (BCST). The tests were administered with a laptop using Psychology Experiment Building Language (PEBL, Version 0.14) software which was developed by Mueller (2015). However, the KBIT-2 was administered according to the protocol by Kaufman and Kaufman (2004).

PPVT is a simple reaction time task, which is used to measure attention (Dinges & Powell, 1985). The test consisted 25 trials, following 6 practice trials. In the beginning of each trial a fixation cross '+' (ready signal) was presented for 100 msec. After that, a stimulus (red circle) was presented at random interval (Fig. 2), participants responded to stimulus by pressing the space bar as soon as they could. During PPVT the time lag between a stimulus and a response was recorded as a reaction time, and was displayed after each response. Following PPVT participants were provided with a rest period of one minute to minimize the effect of fatigue on the following cognitive task, GNG.

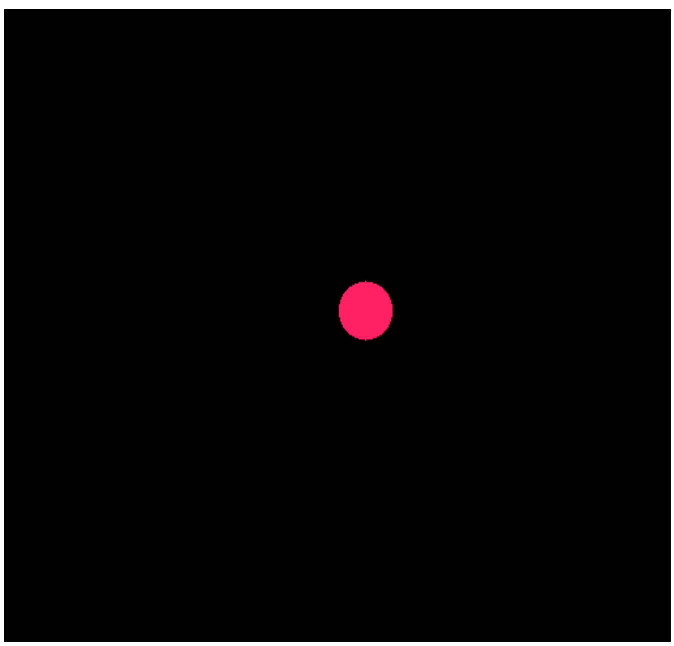


Figure 2: PEBL Perceptual Vigilance Task stimulus.

GNG is used to measure attention and inhibition in terms of commission and omission error. Omission error and commission error are correlated with inattention and hyperactivity respectively (Bezdjian, Baker, Lozano, & Raine, 2009). Omission error is the failure to respond to a stimulus for which participants are supposed to respond, whereas Commission error corresponds to a response to a stimulus for which the participant are not expected to respond. During the test, stimulus ‘P’ and ‘R’ were displayed in the ratio of 3:1 in one of the four squares (Fig. 3). The test consisted of two rounds. Each round had 8 (practice) + 48 (test) stimuli. During round 1, participants were instructed to click the right shift button in response to ‘P’ while not responding to ‘R’, whereas during round 2 they had to click the right shift button in response to ‘R’ while not responding to ‘P’. Negative visual feedback was provided in response to mistakes during a practice session.

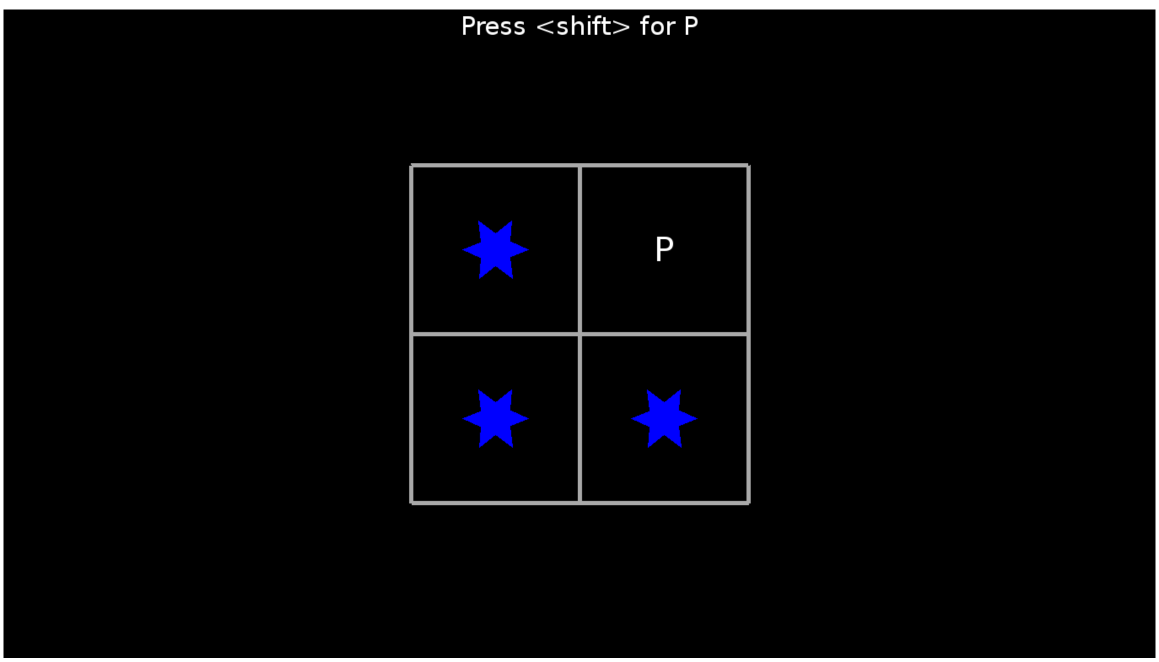


Figure 3: Go/No-Go here, letter P (stimulus) is displayed.

Anthropometrics were recorded in Subject Data form (Appendix H) prior to BCST administration.

BCST is a PEBL version of the Wisconsin Card Sorting Test (WCST), which measures different components of executive function. The test was validated by Fox, Mueller, Gray, Raber, and Piper (2013). During the test, participants were presented with one card at a time, they had to use a mouse to match the card with one of the four cards, which were different from each other in terms of color, shape and number (Fig. 4). The card had to be matched based on one of the three rules, i.e. similarity in color, shape or number. At a time only one rule was correct. In order to match correctly participants had to figure out the exact rule based on visual feedback, which was provided after each response to notify whether the previous match was correct or incorrect. Additionally, the rule changed after every 10 correct responses. Prior to the actual task, participants practiced 10-12 trials and the rule during practice trial changed after 4 correct responses.

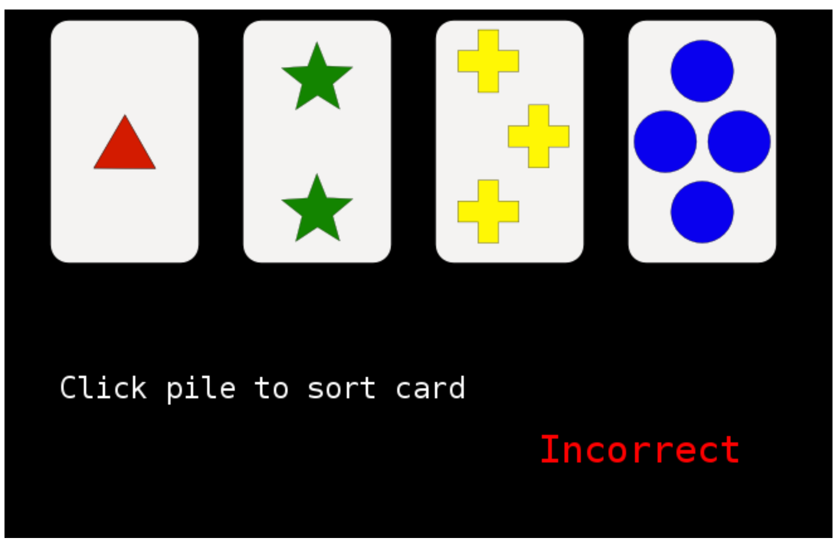


Figure 4: Berg's Card Sorting Test: the set of four cards and feedback (Incorrect) in response to the last card matched.

The experiment was carried out in a lab, which is equipped with a Virtual Reality (VR) system (Fig. 5) that consists of an 180° semi-cylindrical display in front of an instrumented dual belt (1m X 2m) treadmill (Motekforce Link, Amsterdam, Netherlands). It consists of an integrated 10-camera VICON MX motion capture system (Oxford Metrics, Inc., Oxford, UK) to record participant kinematics.

Before stepping on the treadmill, markers were placed on participant's head, feet and pelvis, by utilizing the 16 marker set which has already been established in our lab (Wilken, Rodriguez, Brawner, & Darter, 2012). To prevent falls, all the participants wore a commercially available, safety harness\to an overhead support frame. This harness did not interfere with their normal movements. During trials, the treadmill was set to run at a pre-determined comfortable speed (v_w), calculated as $v_w = \sqrt{(Fr \cdot g \cdot l)}$, where Fr = 0.16 is the Froude number, $g = 9.81\ m/s^2$ and l is the leg length in meters, as we have done previously (McAndrew, Dingwell, & Wilken, 2010; McAndrew, Wilken, & Dingwell, 2011).

During the experimental trials, participants were instructed to hold an android touch screen smart phone (Motorola Moto G) in landscape mode, near their belly button. The participants played a standardized cell phone game (Fish Farts, Version 1.2) (Fig. 6) on the cell phone, during all texting trials. The cell phone game presented to participants had randomly appearing fish and bubbles that moved across the screen, which participants had to tap. The object of the game is simply to tap as many fish/bubbles as you can. The game tracks each user's score in terms of number of fish and number of bubbles tapped. The game is played continuously (there are no "levels" to advance through and it never ends). We chose Fish Farts to represent a simple texting-like task that was easy to learn and as minimally cognitively challenging as possible. This was considered critical to tease apart the effects of visual and cognitive distractions, the cognitive demands were altered in the object negotiation. Game sounds were disabled. Because the game is continuous play without any time limit, it did not interrupt any trials.

Participants walked in a VR environment depicting a city with roads (two lanes) and buildings on sides of the road (Fig. 5). Participants were instructed to walk on one lane at a time (i.e. either left or right), they were instructed to change lane to respond to obstacles and targets. They walked with and without a texting like task on a cell phone while negotiating: “No”, “Simple” or “Complex” objects. For the Simple task, participants were randomly presented with red balls (obstacles) and were instructed to always avoid obstacles by moving laterally to the lane that did not have ball. During the Complex task, participants were randomly presented with either red (obstacle) or green (target) balls and were instructed to always avoid red obstacles and hit green targets by changing lanes as needed (complex task was cognitively more challenging as compared to simple task, individuals had to make additional decision based on the color of the ball during complex task).

Individuals could respond to objects before it crossed them, after which it was considered a failure (i.e. collision). Objects reached the center of the treadmill in two seconds after its appearance. Depending on individual’s location on the treadmill they had about 2 sec to respond to an object (i.e., if ahead of the center, they had less time, whereas they had more time if they were behind the center of the treadmill). Feedback was provided when object crossed participant, positive auditory feedback was provided for successful responses, whereas, both visual and auditory negative feedbacks (resembling collision) were provided, following a collision or failure.

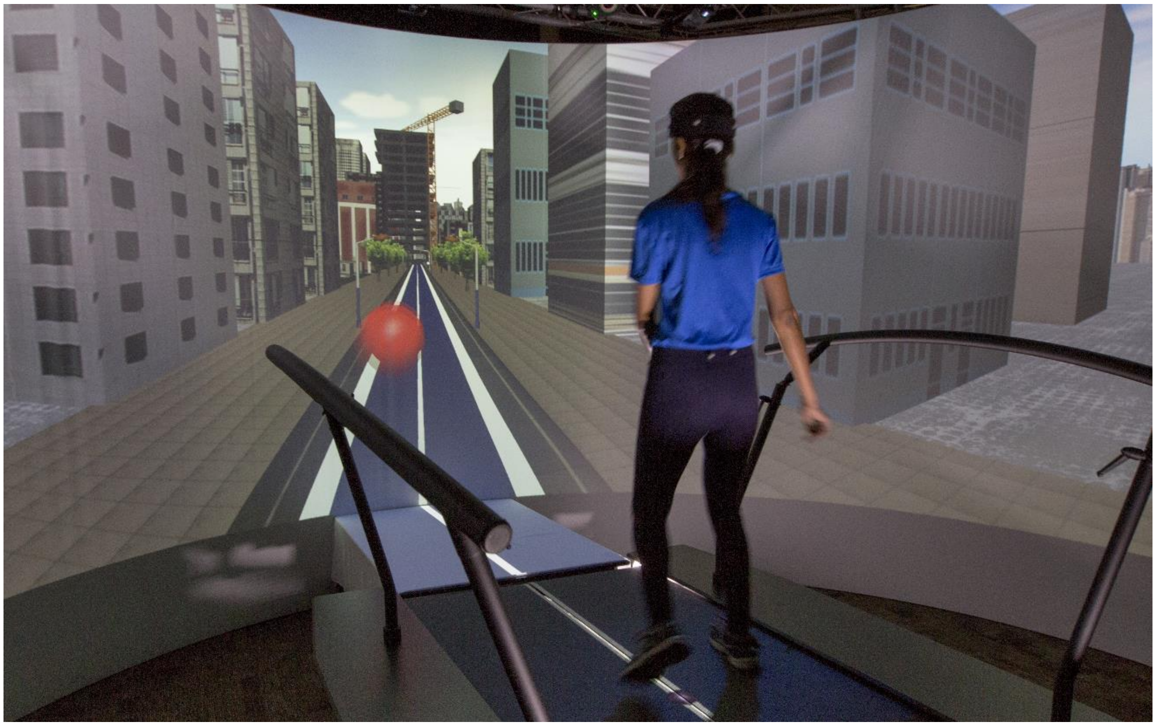


Figure 5: Depicts virtual environment with buildings on the two sides of the road, an obstacle on the left lane and participant changing lane to avoid the obstacle.

Individuals performed texting task for 20 sec while standing, after stepping on the treadmill to get acclimated to the Cell Phone Task. Additionally, 10 min of acclamation period was provided to each participant, during which they were acclimated to the six conditions. There were six conditions, which were combination of the three different environments coupled with texting or no texting. The six conditions were – No Texting-No Object Negotiation (NN), No Texting-Simple Object Negotiation (NS), No Texting-Complex Object Negotiation (NC), Texting-No Object Negotiation (TN), Texting-Simple Object Negotiation (TS), and Texting-Complex Object Negotiation (TC). Participants walked under NS, NC, TS, and TC trials for approximately 3 minutes each, whereas they walked for about 1 min during NN and TN trials, as there were no objects. Each of the six different experimental conditions were performed twice. The order of the presentation of the trials (Appendix I) were randomized using counter balanced Latin square design to minimize learning effects. Participants rested at least one minute between subsequent trials to minimize fatigue.

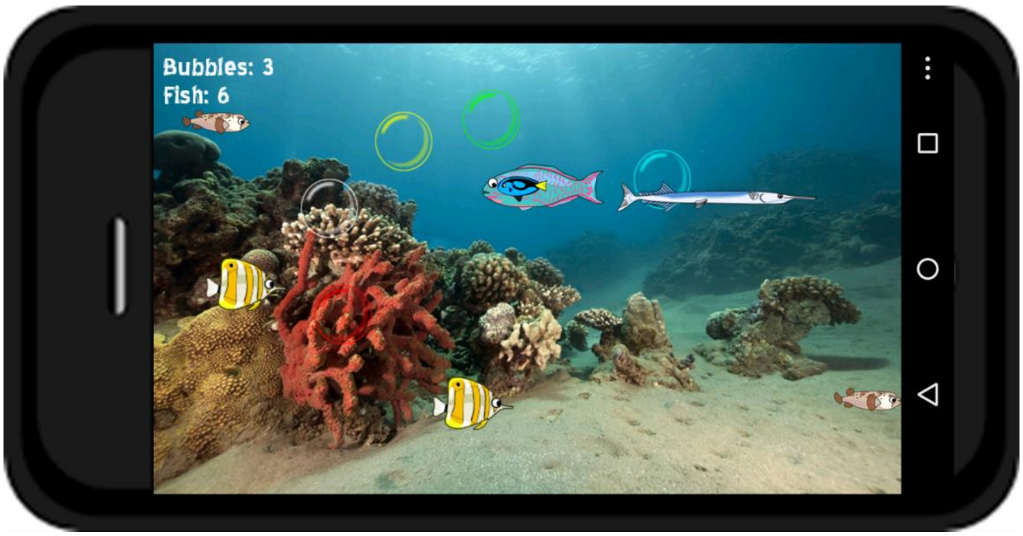


Figure 6: Representation of ‘Fish Farts’ game screen on the cell phone: The score is shown on the top left. Fish and bubbles appear and move randomly, they disappear after being tapped.

Data Collection and Processing

Composite IQ (KBIT_Composite) score was calculated based on the 3 sections of KBIT, it ensured that the participants had similar skills and knowledge acquired through education and acculturation.

For PPVT, reaction time was defined as the amount of time taken to respond to a stimulus, and was calculated by the software. Reaction times in the range of 150 and 500 msec are typically considered to be accurate responses. Therefore, these reaction times were used for the calculation of the mean and the standard deviation of reaction times, which corresponds to a delay and variability in the response, respectively. During the PPVT test all the participants were offered 25 stimuli; however, one individual was accidently offered seven stimuli. This did not affect the calculation of mean and standard deviation for PPVT variables. Mean (PPVT_avg), and standard deviation (PPVT_sd) of reaction times (in msec) were calculated. Additionally, accuracy (PPVT_accuracy) and mean of inverse of reaction time (PPVT_Mean1overRT) was also calculated.

During GNG, the software calculated reaction times and the number of correct responses to letter P and R during each round. Data for one participant was removed from analysis of GNG variables because the participant failed to participate in first round of the GNG test. Utilizing the variables calculated by the software, Omission error (GNG_Omission_Error), commission error (GNG_Commission_Error), mean (GNG_avg) and standard deviation (GNG_sd) of reaction times (in msec) of all the responses (correct and incorrect) were calculated.

The PEBL software was used to calculate various measures of executive functions, including the perseverative error (BCST_PE) (incorrect response which would have been correct for previous rule), perseverative response (BCST_PR), and failure to maintain a set (BCST_FMS), number of categories completed (BCST_Categories_Complete). Where, FMS is a measure of attention and categories completed is a measure of abstraction (Tanaka et al., 2009). Additionally, the number of perseverative errors and perseverative responses are measures of Cognitive flexibility (Anokhin, Heath, & Ralano, 2003). The software also calculated reaction times (in msec). Mean of all the reaction times (BCST_avg) were calculated using MATLAB.

During walking, kinematic data was recorded from markers placed on individuals. Raw kinematics data was processed using Vicon Nexus. Additional, data processing and analysis was performed using Matlab (MathWorks, Inc., Natick, MA) and SPSS software for windows (SPSS, Inc., Chicago).

During texting condition (TN, TS and TC) total number of fish and bubbles tapped and duration of trial were recorded for each trial. Game score was defined as average number of fish and bubbles tapped per sec, across two trials. It was calculated by dividing the total number of fish and bubbles tapped across two trials by the total time for the two trials. GS was utilized to determine the performance on the cell phone task, higher GS corresponded better performance.

For each object encounter, Movement Time (MT) (in sec) was defined as the time taken to move laterally from the lane the participant was currently walking in to the other lane, in order to avoid an obstacle or hit a target. Participant lateral movement was determined by the location of the center of their pelvis, which was calculated as the geometric centroid of the 4 markers placed on the pelvis. Movement time was calculated as the difference of the time when the geometric centroid of the 4 pelvis marker shifted to a different lane from the time when the object appeared. Mean and standard deviation of MT across two trials were calculated for individual experimental conditions involving object (i.e. NS, NC, TS, TC), across two trials.

Percent Collision was calculated for conditions during which objects were presented (i.e. NS, NC, TS, TC). It was defined as total number of failures divided by the total number of (correct and incorrect) responses × 100 %. Percent Collision was calculated across the two trials for each condition.

DATA ANALYSIS

Out of all the 14 cognitive test variables that are generally reported, 2 were not utilized for further analysis, as they were significantly correlated to other two variables, described in (Appendix J). Cognitive test statistics were calculated which includes mean and standard deviation of the reduced cognitive test variables (Appendix K).

Cell phone task performance was determined on the basis of Game Score, higher score corresponded better performance. There were no game scores for the conditions that did not involve texting. Therefore, we compared Game Score for the three tasks that involved texting, i.e. TN, TS and TC using a single-factor Analysis of variance (ANOVA) with complexity of the obstacle avoidance task as a factor. We expected Game Score to decrease with an increase in the complexity of the obstacle avoidance task.

Percent Collision measured failure to avoid an obstacle. We hypothesized that, Percent Collision would be higher while texting, and it would also increase with an increase in the complexity of the Object Negotiation. To test these hypotheses we compared Percent Collision across all of the experimental conditions that involved objects (i.e. NS, NC, TS, TC), using a 2 X 2 ANOVA with texting and object complexity as factors.

We compared mean and standard deviation of Movement Time under different conditions to quantify the effect of the complexity of the object negotiation and texting on delay in response to an approaching object. An increase in the Mean Movement Time corresponds to higher delay in the response, whereas an increase in the Standard Deviation of Movement Time corresponds to more variable responses. We expected the Mean of Movement Time to increase due to texting and also due to the increase in the complexity of the Object Negotiation. To test these hypotheses, we conducted two separate 2 X 2 ANOVA for Mean and Standard Deviation of Movement Time with Texting and Object Negotiation complexity as factors. Mean and Standard Deviation of Movement Time was calculated only for NC, NS, TC and TS conditions, since no objects were presented during NN and TN conditions.

Linear correlation analyses of cognitive variables with performance on cell phone (during TN, TS and TC) and object negotiation (during NS, NC, TS and TC) (Appendix L) were used to quantify the extent to which the Baseline Cognitive Scores (from PPVT, GNG and BCST) could predict subsequent performance on both the Texting (Game Score) and the Object Negotiation (% Collision, Mean of MT and Standard deviation of MT).

Chapter 3: Result

In the results section of this paper the game score, percent collision and movement time during different conditions are reported. We also described the correlations between cell phone and obstacle avoidance performance with individual's cognitive capacity.

Cognitive Measures	Mean ± SD
PPVT_avg (msec)	336.03 ± 39.53
BCST_FMS	1.16 ± 1.34
BCST_PE (%)	11.88 ± 5.10
BCST_PR (%)	32.47 ± 4.91

Table 3: Descriptive statistics of the baseline cognitive measures

GAME SCORE

There was a significant effect of the complexity of the Object Negotiation on the Game Score, ($F_{(2,87)} = 49.46$, $p < 0.001$). Performance on Texting was adversely affected with Object Negotiation. Post Hoc analysis showed that, Game Score for TN was significantly more than TS ($p < 0.001$) and TC ($p < 0.001$). GS during TS (Mean = 1.01, SD = 0.19) and TC (Mean = 0.99, SD = 0.16) was lower than TN (Mean = 1.36, SD = 0.13). However, Game Scores was not different ($p = 0.85$) for TS and TC, which had the different complexity of the Object Negotiation. Thus, Game Score was significantly reduced when objects were present, but was not affected by the complexity of the Object Negotiation (Fig. 7).

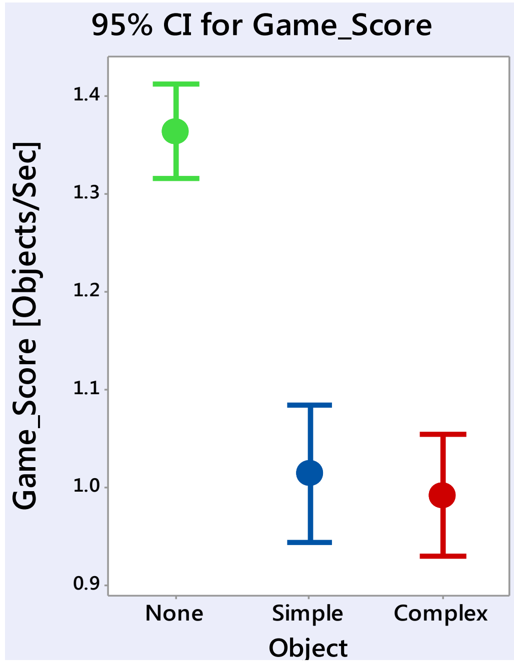


Figure 7: Game Score during cell phone use, while negotiating No, Simple and Complex Objects.

Percent Collision

Percent Collision increased significantly with Texting ($F_{(1,87)} = 121.62$, $p < 0.001$) (Fig. 8). % Collision was lower for No Texting conditions, NS (Mean = 1.26, SD = 3.15) and NC (Mean = 1.81, SD = 2.75) as compared to Texting conditions, TS (Mean = 15.36, SD = 12.29) and TC (Mean = 18.43, SD = 12.95). However complexity of the Object Negotiation did not affect collision with objects ($F_{(1,87)} = 1.69$, $p = 0.19$). Thus, collisions were increased with Texting, but did not change with an alteration in the complexity of the object Negotiation. There was no Text X Object interaction ($F_{(1,87)} = 0.81$, $p = 0.36$).

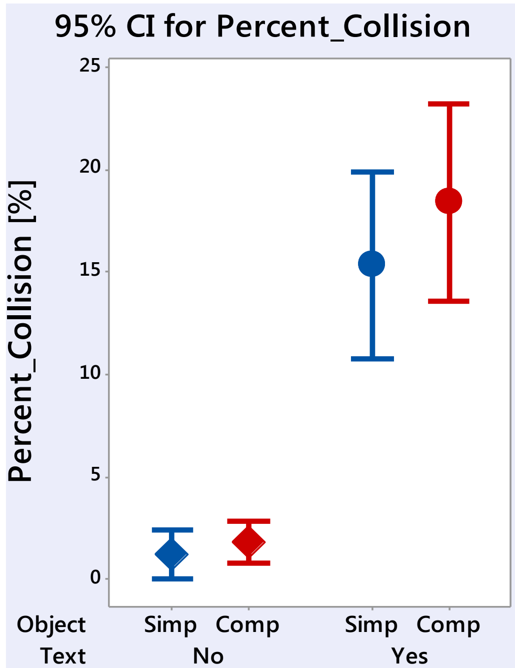


Figure 8: Percent Collision with and without Texting, while negotiating No, Simple and Complex Objects.

Movement Time

Mean Movement Time increased significantly due to texting ($F_{(1,87)} = 56.21$, $p < 0.001$) (Fig. 9), it was higher for Texting conditions, TC (Mean = 1.51, SD = 0.09) and TS (Mean = 1.45, SD = 0.09) as compared to conditions that did not involve Texting, NC (Mean = 1.42, SD = 0.09) and NS (Mean = 1.37, SD = 0.10). Additionally, Mean Movement Time increased due to an increase in the complexity of the Object Negotiation ($F_{(1,87)} = 20.99$, $p < 0.001$). There was no significant Texting × Object Negotiation interaction effect, indicating that the effects of the Object Negotiation and Texting were independent. Mean Movement Time increased with Texting and with an increase in the complexity of the Object Negotiation.

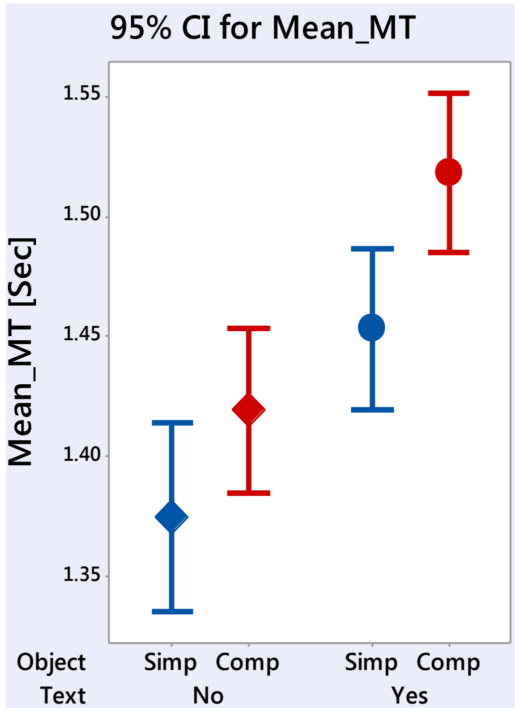


Figure 9: Mean Movement Time (Mean MT) with and without Texting, while negotiating No, Simple and Complex Objects.

Standard Deviation of Movement Time was significantly increased with Texting ($F_{(1,87)} = 107.64$, $p < 0.001$) (Fig. 10). However, it was not affected by the complexity of Object Negotiation ($F_{(1,87)} = 0.25$, $p = 0.61$). Thus, Movement Times were more variable when participants were Texting but did not alter by the complexity of Object Negotiation. There was no Text X Object Negotiation interaction ($F_{(1,87)} = 0.36$, $p = 0.55$).

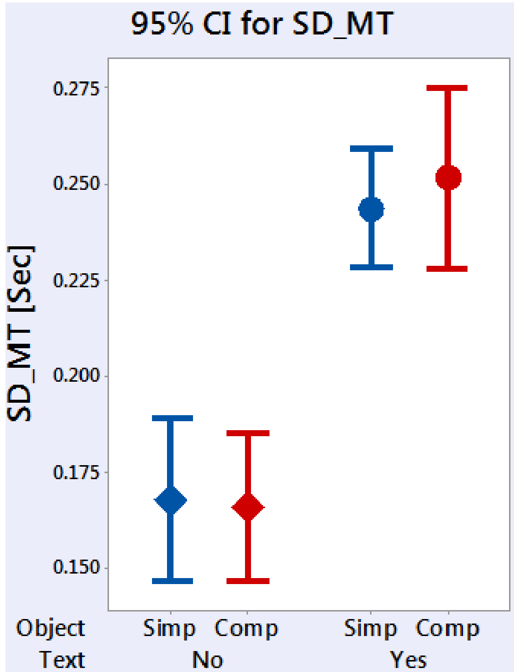


Figure 10: Standard Deviation of Movement Time (SD_MT) with and without Texting, while negotiating No, Simple and Complex Objects.

CORRELATIONS BETWEEN COGNITIVE SCORES AND PERFORMANCE ON CELL PHONE AND OBSTACLE AVOIDANCE TASK

As shown above, Texting and Object Negotiation performances were different across the conditions, indicating that the six experimental conditions (i.e. NN, NS, NC, TN, TS and TC) were distinct from each other. Therefore, linear regression analyses of cognitive measures with Texting and Object Negotiation performances, were conducted separately for different experimental conditions.

Performance on Texting and Cognitive Capacity

Baseline Cognitive Capacity predicted the performance on the cell phone task when either Simple or Complex Objects were present in the environment (Fig. 11). Game Score during TS and TC conditions were significantly correlated ($p < 0.05$) to Perseverative Error (BCST_PE) and Perseverative Response (BCST_PR). Game Score was higher for individuals with low Perseverative Error and Perseverative Response in the presence of objects in the environment. However, these correlations were not significant when there was No object in the environment. Furthermore, Game Scores were not calculated for conditions not involving cell phone use (i.e. NN, NS and NC).

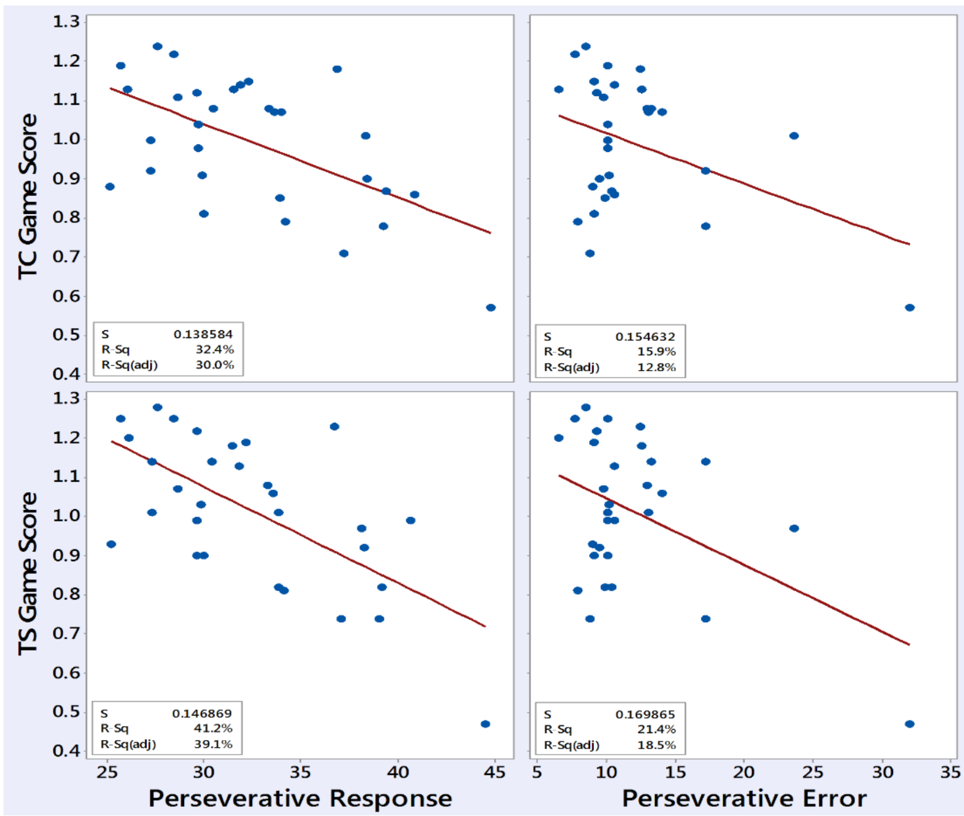


Figure 11: Game score during cell phone use was correlated to BCST_Perseverative Response (Perseverative Response) and BCST_Perseverative Error (Perseverative Error) in the presence of Simple (TS) and Complex (TC) objects in the environment.

Performance on Object Negotiation and Cognitive Capacity

Ability to successfully respond to an approaching object was correlated to ($p < 0.05$) Reaction Time during PPVT and Failure to Maintain Set during BCST (i.e. PPVT_RT and BCST_FMS) during TS and TC. However, these correlations were not significant during NC and NS (Table A). Individuals with higher Reaction Time and Failure to Maintain Set had higher Percent Collision (Fig. 12) during TS and TC. However, correlations were not significant during NS and NC. Additionally, percent collision was not calculated for no object conditions i.e. NN and TN.

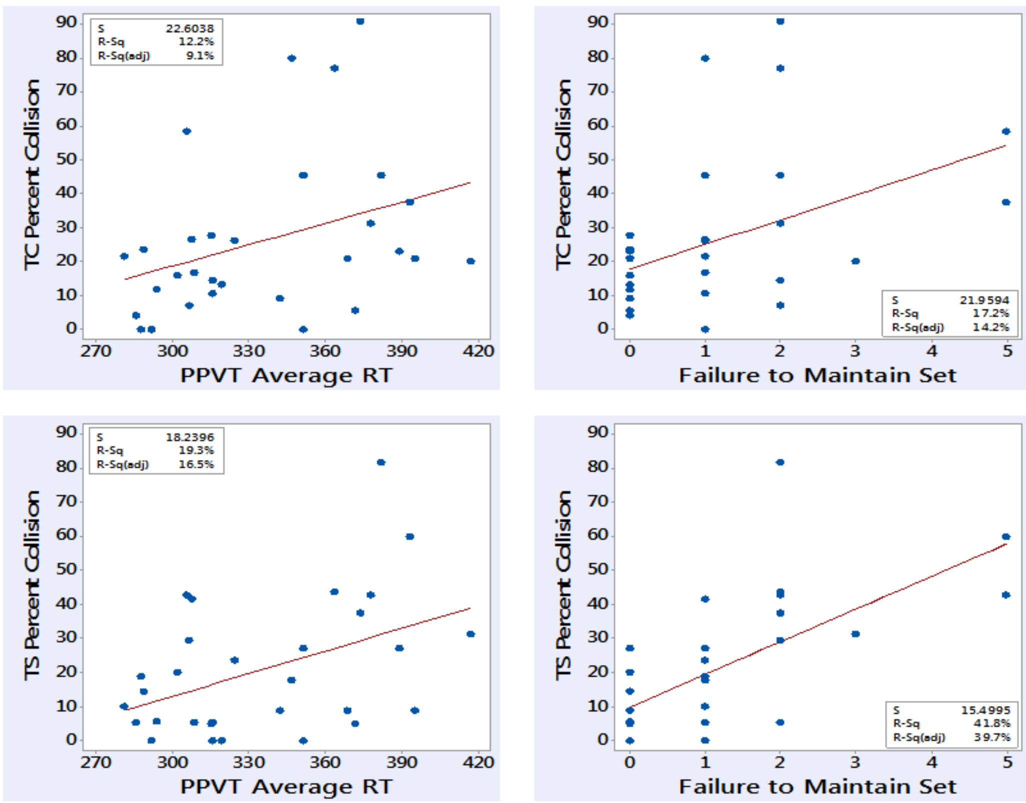


Figure 12: Percent collision was correlated to Reaction Time during PPVT (PPVT Average RT) and Failure to Maintain Set during BCST (Failure to Maintain Set) during TS and TC.

Chapter 4: Discussion

Participants were asked to walk on a treadmill and avoid randomly appearing obstacles (red balls) by shifting laterally, to understand how the increasingly common cell phone use during walking affects individual's responses to approaching obstacles. The use of a cell phone by pedestrians can introduce both visual and/or cognitive distractions, which can affect pedestrian safety, as vision (Logan et al., 2010; Patla, 1997) and cognition (Al-Yahya et al., 2011) play a significant role while walking. In the present experiment, visual distraction was provided by a cell phone and cognitive demands were altered for the obstacle avoidance.

We used 'Fish Farts' to represent texting like task, it introduces visual complexity and is cognitively minimally challenging (which allowed us to separate out the effects of visual and cognitive complexity, any difference in the performance due to the cell phone task can be considered as the effect of visual complexity whereas differences in performance due to the complexity of obstacle avoidance can be measured as the effect of cognitive complexity). There were three different levels of obstacle avoidance – No, Simple and Complex Object Negotiation.

We found a significant decrease in the Game Score with the obstacle avoidance. During (TN), individuals could look at the phone without any distraction as condition there were no objects in the environment. We know texting speed decreases due to performing an additional task that involves vision (Lim, Amado, Sheehan, & Van Emmerik, 2015). Here, the Object Negotiation required participants to shift vision, thus leading to a decrease in the Game Score. However, Texting performance was unaffected by the complexity of Object Negotiation. Thus, Game Score was affected due to the shift in visual attention, but was unaffected by the additional complexity in the obstacle avoidance task, i.e. making decisions based on the color of the ball.

Percent Collision, which measured the (in) ability to avoid obstacles and hit targets, increased with the cell phone (i.e. visual task) use. This result is similar to the finding that ability to avoid an obstacle decreased with an additional visual task (Chen et al., 1996). In our study, cognitive complexity of the environment did not affect Percent Collision. This could be because the additional decision making (based on color of the object) during Complex Object Negotiation may not have been able to elicit significant difference between performance in Simple and Complex Object Negotiation.

Additionally, ability to avoid an obstacle was not affected by an increase in the cognitive complexity of the secondary task (Chen et al., 1996). Furthermore, the impact of a secondary cognitive task on ability to avoid obstacles reduces when individuals have more time to respond (Weerdesteyn, Schillings, Van Galen, & Duysens, 2003). Thus, the effect of cognitive complexity of the Object Negotiation on Percent Collision may be seen if the time available to respond to an obstacle (which was ~ 2 sec) is reduced.

Furthermore, Variability of Movement Time was increased due to the Texting but was unaffected by the complexity of Object Negotiation. Individual's had to shift visual attention between the cell phone and the environment (road) to perform Texting and Object Negotiation simultaneously, and the obstacles were presented randomly. Thus, randomness in presentation of obstacle and shift of visual attention led to variation in the amount of time taken to perceive an obstacle, which in turn may have increased the overall Variability of Movement Time. After viewing an object, individuals may have taken the approximately same amount of time (i.e. no variability) to make a decision and perform the movement for each object within the same condition, thus Variability of Movement Time was not affected with the complexity of Object Negotiation.

As predicted, we observed an increase in the Movement Time with an increase in the cognitive (i.e. complexity of Object Negotiation) as well as visual (Texting) demands and the effect of both the demands were independent. Cell phone use leads to a delay in the detection of visual signal by pedestrians (Haga et al., 2015), which may have led to the delay in the movement time.

Avoiding obstacles can be considered as a two-step process (i.e. planning movement and performing movement). Thus, Movement Time comprises of planning and movement execution period. Movement execution period (i.e. time taken to change lane) can be assumed to be independent of Texting and cognitive complexity of the Object Negotiation. Thus, difference in Movement Time can be attributed to planning period. Likewise, cell phone use leads to a delay in the initiation of a movement (Banducci et al., 2016; Byington & Schwebel, 2013) but does not affect the street crossing duration (Banducci et al., 2016).

People with better cognitive capacity performed better on both cell phone and obstacle avoidance task, when they had to do both the tasks concurrently. Those who responded quickly on PPVT were able to respond successfully to objects within available time (lower % Collision) when using a cell phone while avoiding obstacles. This is similar to a finding, people with higher processing speed are more successful while crossing street (Chaddock et al., 2011). Additionally, people with higher number of Failure to Maintain Set during BCST had more collisions with obstacles, when using cell phone while avoiding obstacles. We know that individuals who have higher number of Failure to Maintain Set during BCST, have more trouble in following a pattern after learning it. Thus, the task of avoiding obstacles while using a cell phone may have required individuals to learn a pattern and follow in order to successfully respond to objects while using a cell phone.

However, correlation of Percent Collision with Reaction Time (PPVT) and Failure to Maintain Set (BCST) were not significant when participants were just Negotiating Objects and Not Texting. The Object Negotiation by itself may not be cognitively demanding to elicit significant correlations, but correlations became significant when Texting was coupled with Object Negotiation. Correlations may be insignificant due to a ceiling effect under non-texting conditions, as out of 30 participants, 25 did not have any collision when only obstacles were presented and 20 had no collision when both obstacles and targets were presented, while Not Texting. This ceiling effect could be reduced by decreasing the amount of time available for response as ability to avoid an obstacle increases when time available to respond is high (Chen et al., 1996).

Individuals with higher Perseverative Error and Perseverative Responses are considered to have lower cognitive flexibility (Anokhin et al., 2003). While responding to obstacles simultaneously, individuals with higher Cognitive Flexibility were better at the cell phone task. However, Cognitive Flexibility was a predictor of performance only during dual task performance. When participants performed either of the two tasks (i.e. Cell phone or obstacle avoidance task) individually, their performance was not correlated to cognitive flexibility. This could be because the Cognitive Flexibility does not play significant role when individuals perform single task.

We found that the use of a cell phone by pedestrian can adversely affect their safety. It increases the likelihood of getting hit by an obstacle. These effects were caused mainly due to the visual demands of a cell phone, and were less affected by the cognitive demand of the task. Additionally, individuals with better cognitive capacity were better able to perform both cell phone and obstacle avoidance task.

Authorities are taking various steps to prohibit pedestrians from using handheld devices (Mwakalonge et al., 2015). The outcome of this study provides evidence to support the existing effort to discourage pedestrians to use cell phone while walking. Furthermore, information about the effect of the complexity of the environment (i.e. Obstacle avoidance task) can be utilized to make decisions related to cell phone use in different environments. We found that the baseline cognitive capacity affects performance, training to improve the baseline cognitive capacity may improve their performance.

Some cell phone applications (e.g. Type n walk – available on i phone, Transparent screen – available on android phones) are introduced to allow pedestrians to see the environment when using cell phone. These cell phone applications utilize cell phone camera to capture what is ahead of them and display it on the background of the cell phone screen. Understanding the underlying cause of the increase in the risk due to a cell phone use can facilitate the development of appropriate applications for cell phone.

This study was conducted on young, healthy adults, therefore we do not know if similar changes in behavior due to cell phone use would be seen among people of different age or by persons with either physical and / or cognitive impairments, etc. People between the age of 18 and 29 years are considered to be at their peak cognitive stage due to which there may not be much difference between their cognitive capacities, which may have affected the linear analysis among cell phone and obstacle avoidance task performance with cognitive capacity. Recruiting people with different level of cognitive capacity may help in better understanding of the relationship between cognitive abilities and performance.

There was a significant effect of environmental complexity on the movement time, but Percent Collision and Game Score were not affected by increase in the complexity of the obstacle avoidance task. The difference in the complexity of the obstacle avoidance task may not be sufficient to elicit the decline in success rates, and cell phone task performance. Therefore, studying responses at different level of cognitive and visual complexity on a cell phone (i.e. Texting) and environmental task (i.e. Obstacle avoidance) may provide more insight on the effects of cell phone and environment on performance.

We found that individuals who were unable to follow a pattern after learning it had more collisions. This indicates that one may need to follow some strategy to use cell phone and negotiate obstacles. However, the current study is limited to understanding the effect on performance due to the cognitive and visual complexity introduced by cell phones. Work can be extended to study strategies that are adapted (i.e. Specific period in the gait cycle when people choose to shift visual attention and / or shift lane? Do people with difference in cognitive capacity choose different strategies?).

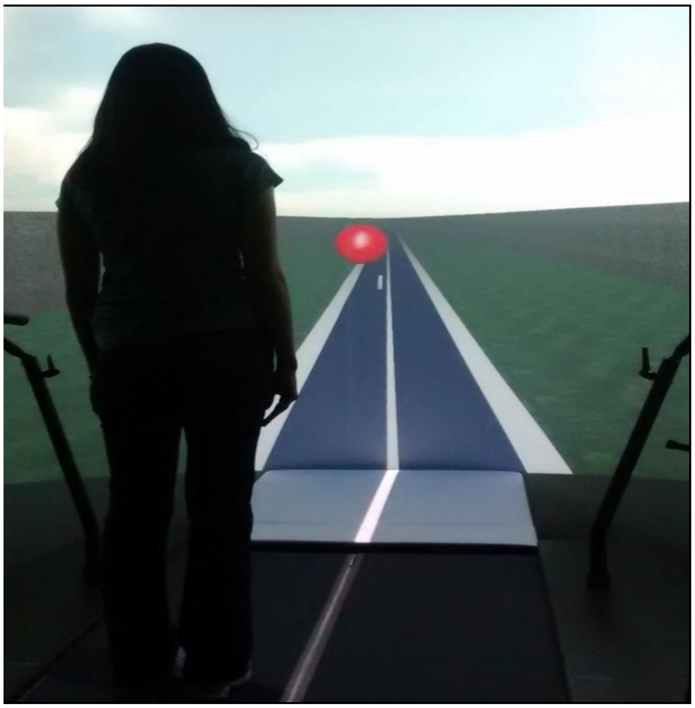
Cell phone use by pedestrians reduces their ability to perceive an obstacle and move away from it. This increases the likelihood of getting hit by various stationary and moving objects (like car, other people, and pole). Individuals become less aware of their surrounding when using a cell phone, they sometimes fail to recognize an unsafe individual, or a situation around them. Avoiding cell phone use while walking can improve pedestrian safety by allowing individuals to be more aware of their surroundings, and take actions quickly when needed.

Appendices

Appendix A - Flyer

WALKING WHILE TEXTING STUDY

A research study to determine how using cell phone affects people's ability to avoid obstacles while walking



We are Recruiting:

- Healthy Male and Female Participants
- 18 to 35 Years Old
- Regular Smart Phone Users

Study Contact: Preeti Chopra

Nonlinear Biodynamics Lab (BEL 530)

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Appendix B – Checklist

<table>
<tr><td></td><td>Calibrate Camera</td></tr>
<tr><td></td><td>Open D flow

☐ Uncheck Do not trigger two events in a row.
☐ Open global stop watch
☐ Open random time watch
☐ Open MT watch,
☐ Open game time watch
☐ Open Random Set
☐ Source Live
☐ Don’t show markers.
☐ Open Counter for strides
☐ Open video in Motek
☐ Set D Flow volume to maximum
☐ Put file names as PLone- 5 Files (4 changes every time.)
☐ Keep Calculator
☐ Write trials on Trial sheet.

VICON
☐ Calibration
☐ Set origin
☐ Participant, session, create foot self-paced, static, save, save model.

☐ Keep markers ready.
☐ Measuring tape
☐ Duct Tape

GET
☐ Calculator
☐ KBIT
☐ Laptop
☐ Mouse
☐ Charger
☐ Candy
☐ Water

• Unplug lab phone</td></tr>
<tr><td></td><td>Cognitive test

☐ Full screen
☐ Mouse</td></tr>
</table>

	☐ PVT name ☐ Tick KBIT
	Phone ☐ Remove password from phone ☐ Turn game volume OFF ☐ Turn flight mode ON
	Consent Form
	Visual Color Discrimination Test (Till 4th green)
	KBIT • Give it a try | | You can do it | | It's okay to guess • Choose one of them | | which one is it • Riddles- Answer should be one word. • Nice try | | That was hard one. | | That was difficult. • Record both correct and incorrect and learning responses. Basal Rule- first 3 from item 25 are correct else go back to item 20 again check 3 correct then continue from there and skip earlier asked question. Ceiling- when 4 continuous responses are incorrect. Stop that section. Ceiling score is the highest score.
	Health History, Cell Phone and Handedness • Main occupation • Consider sports as any type of physical activity. • Cell phone usage- consider walking + using cell phone as 100% • You will hold phone in landscape.
	Ask participant to keep phone aside

	PVT
	o In this test you will be presented with a red ball. You have to respond to red ball by hitting space bar as quickly as you can. Before each red ball you will be presented with a "+" which is a signal for you to be "READY".
	o Make sure you read instructions on computer.
	o Ready for the practice?
	  o LPone (Give correct test)
	o Are you ready to take the test?
	  o TPone (Give correct test)

	o 1 min rest
	Go- No- Go o The task has two parts. o In the first part you have to hit right shift button as quickly as possible when you see letter P on any one of the four squares on the screen.

	○ Do not respond to letter R. ○ In the second half you have to hit shift button as quickly as possible when you see letter R on any one of the four squares on the screen. Do not respond to letter P. The computer will inform you before the second part starts. ○ Are you ready for the practice? After practice the test will start. You will be presented with a message before the actual test starts. ○ Pone(Give correct test) ○ Make sure you read instructions on computer.
	Subjects Measurements

	WCST
	○ Initially on the computer screen you will see four cards and a pile of extra cards.
	○ For this task you will be using mouse to select one of the four cards where you would like to stack the fifth card.
	○ You need to try to organize the fifth card by color, shape or the number of objects on the card.
	○ A pattern will emerge based on either color, or shape or number of objects on the card.
	○ At some point during the testing the sorting rules will change and you will then have to change the sorting pattern.
	○ The rules may change more than once
	○ After each turn you will be told if you have sorted the card into the correct pile or not.
	○ Try to sort cards as correct as you can.
	○ Make sure you read instructions on computer.
	    ○ Card sort, LAST ONE FULL WCST
	○ Now you will get a chance to practice.
	    ○ LPone- stop after 10-12, NO FULL SCREEN (Give correct test)
	○ Are you ready to take the test?
	    ○ TPone (Give correct test)

	□ Ground Projector □ 3 Projectors □ Flight mode
	Check if participant has marker (Tell how to step in) Put Markers, extra tapes
	Place Harness
	Collect static trial
	GAME □ Bubbles and fish will appear on the screen at random.

	☐ You will have to hit them to earn points. You will get equal points for bubble and fish. ☐ You will not get extra points for hitting same fish or bubble twice. ☐ Hit as many fishes and bubbles as you can. ☐ Demonstrate to participant how to restart game ☐ I will give you 20 sec to practice game ☐ Can you play game for one minute
-	• You will walk on treadmill during the experiment at a fixed speed. • Do not walk off the treadmill. • There is a sensor at the back. If you reach there the treadmill will stop. • In front there is a white sheet do not step on that. • During all the trials you will hold the cell phone near your belly button. • During texting conditions, you will play the game on phone. Please start playing the game as soon as you are instructed to “START” walking and stop when you instructed to “STOP” walking within the VR environment. • Treat two sides of treadmill as two different lanes of a road. • Do not walk on middle of the road but you can shift from one side of the road to the other side. • While walking you will be presented with balls moving towards you within the virtual environment. • You have to avoid the red balls and hit the green balls by shifting lanes. • Try to move to desired lane as quickly as possible. • I will describe each scenario to you before it begins. Do you have any questions?
	BEFORE WE START COLLECTING DATA I AM GOING TO HAVE YOU PRACTICE SOME CONDITIONS ON THE TREADMILL I will inform you when I start the test.
	TRIAL SHEET
	Write Pone on all- papers.
	Instructions for file name (For any reason if you have to repeat trial name the corrected i.e. new file name as old_1, old_2….)
	PROCESS DATA ☐ Select by hitting space bar ☐ Batch processing ☐ Check that in Pipeline all boxes are checked ☐ Reconstruct walking ☐ Play

	BACK UP DATA
	• Sync back free
	• Right click
	• Run
	• Continue Run
	    □ Run both in D flow
	    □ Run Mocap 1

Trial	Instruction
NN	There are no balls. Hold the phone near belly button. Do not play the game.
NS	Avoid red balls by shifting lanes. Move to desired lane as quickly as possible. Hold the phone near belly button. Do not play the game.
NC	Avoid red balls and hit green balls by shifting lanes. Move to desired lane as quickly as possible. Hold the phone near belly button. Do not play the game.
TN	There are no balls. Hold the phone near belly button. Start playing game when you start walking and stop the game when you stop walking.
TS	Avoid red balls by shifting lanes. Move to desired lane as quickly as possible. Hold the phone near belly button. Start playing game when you start walking and stop the game when you stop walking.
TC	Avoid red balls and hit green balls by shifting lanes. Move to desired lane as quickly as possible. Hold the phone near belly button. Start playing game when you start walking and stop the game when you stop walking.

	Time (s)	
	Beginning	Trials
NN	30	60
NS	120	180

NC	180	180
TN	30	60
TS	120	180
TC	180	180

APPENDIX C - IRB APPROVED CONSENT FORM

IRB USE ONLY
Study Number: 2015-03-0038
Approval Date:
Expires:
Name of Funding Agency (if applicable):

Consent for Participation in Research

Title: "Walking Balance While Texting on Cell Phones"

Introduction

The purpose of this form is to provide you information that may affect your decisioCn as to whether or not to participate in this research study. The person performing the research will answer any of your questions. Read the information below and ask any questions you might have before deciding whether or not to take part. If you decide to be involved in this study, this form will be used to record your consent.

Purpose of the Study

You have been asked to participate in a research study about effects of using cell phones while walking. The purpose of this study is to find out how using cell phones affects how people respond to obstacles appearing in their path while walking. We expect our results may help us better understand and reduce pedestrian accidents.

You have been chosen to participate in this study as part of a group of up to 30 healthy volunteers between the age of 18 and 35 years. You should have no history of physical or neurological problems that might affect your ability to walk on a treadmill.

What will you be asked to do?

You will be asked to complete the following procedures during a single experimental visit:

- You will be asked to report to the Nonlinear Biodynamics Laboratory at the University of Texas at Austin, located in Bellmont Hall, Room 530. Wear comfortable shorts and shoes appropriate for extensive walking. Bring a sleeveless shirt, preferably a tank top. Gentlemen may be asked to perform shirtless.
- Before being admitted to the study, you will be screened for your suitability to participate by completing a brief Health History Questionnaire. You will also be asked about your typical weekly exercise habits.
- If you qualify to participate in the study, we will measure your height and weight, as well as the lengths of various individual body segments, including thigh, lower leg,

and foot lengths, hip width, etc. These measurements do not hurt or feel uncomfortable.

- During walking tests, you will be asked to perform a specified texting-like task (game) on a touchscreen cell phone. To get used to performing this task, you will be asked to perform this cell phone task while seated for approximately 5-10 minutes.
- To get used to walking on the treadmill, you will be asked to walk for 5-10 minutes at a comfortable speed. To get used to the obstacle avoidance tasks, for part of this time, we will also present to you some of these obstacles to be used during the testing trials.
- Next, you will be asked to wear small reflective markers attached to various points on your body to record the movements of your body segments. These markers will be attached with double-sided tape.
- You will then be asked to complete a series of 12 walking trials. Each trial will last 3 to 4 minutes. For each trial, the treadmill speed will be set to a moderate comfortable speed.
- During half of these trials, you will also be asked to play the texting game on the touchscreen phone. In some trials, you will also be asked to perform the task of dodging obstacles that appear in your path while you walk.
- You will be allowed at least 1 minute, or as much time as you need, to rest between trials.
- You can stop the warm-up or any of the trials at any point and for any reason.
- Your participation will involve a single experimental session, lasting approximately 2½ hours.
- The study will include approximately 30 participants
- Your participation may be video recorded and/or photographed if you also consent to this.

What are the risks involved in this study?

The above procedures are not expected to be painful or uncomfortable in a healthy individual. If you do find any of the procedures to be prohibitively uncomfortable, you should immediately tell the investigator and they will be discontinued. None of the devices being used in this study are invasive.

- While walking on the treadmill, there is a risk you might stumble and/or trip. There is also a possible risk of injury from stepping up onto or down off of the treadmill that is elevated approximately 18 inches above the floor. To reduce these risks, you will be asked to wear a safety harness that will catch you in the event of a fall while not constricting your movements. The treadmill is also equipped with an emergency

"STOP" button that the investigator conducting the experiment will control. In the event of any unwanted event, the investigator will press this button to stop the treadmill immediately.

- As during any moderate exercise, there is a risk of heart attack or stroke. This risk will be minimized by asking you to complete the Health History Questionnaire to ensure you are physically active and do not have any illnesses or injuries, or are taking any medications that might indicate that you would be at undue risk of experiencing a heart attack or stroke.
- Again, as during any moderate exercise, while walking on the treadmill there is a risk that you could experience a muscular injury, such as a muscle strain. Also, it is possible that muscle soreness may develop 24 to 48 hours after testing. To help reduce these risks, you will be allowed as much time as you need to rest between trials to minimize the effects of fatigue.
- During walking trials, there is a risk you may become overexerted and tired. To reduce this risk, you will not be asked to perform any tasks beyond the scope of what you might do during your normal daily activities or during moderate exercise. Additionally, you will be allowed to rest as long as you need between trials, and you may stop at any time if you feel the need.
- Some slight discomfort may also be experienced during removal of the reflective markers, similar to removing a band-aid. If you experience skin irritation, this should subside on its own by the following day.
- There may also be additional risks that are unknown at this time. If you wish to discuss the information above or any other risks you may experience, you may ask questions now or contact the Principal Investigators listed on the front page of this form at any time.

What are the possible benefits of this study?

There are no direct benefits to you by participating in this study.

We hope this study will contribute to a better understanding of how using a cell phone can affect how well people can avoid hazards (obstacles) while walking, and thus ultimately help us find ways to reduce pedestrian accidents.

Do you have to participate?

No, your participation is entirely voluntary. You may decide not to participate at all or, if you start the study, you may withdraw at any time. Withdrawal or refusing to participate will not affect your relationship with The University of Texas at Austin (University) in anyway.

What are the alternatives to participating in this research?

Your participation in this study is entirely voluntary. You are free to refuse to be in the study, and your refusal will not influence current or future relationships with The University of Texas at Austin.

Will there be any compensation?

You will not receive $20.00 at the end of the study

What if you are injured because of the study?

By participating in this study, there is a small chance of being injured, as discussed above. If you are injured, the University has no program or plan to provide treatment for research-related injury or payment in the event of a medical problem. The University also has no program or plan for continuing medical care and/or hospitalization for research-related injuries or for financial compensation. In the event of a research-related injury, please contact the principal investigator. Eligible University of Texas at Austin students may be treated at the usual level of care with the usual cost for services at the Student Health Center, but no payment can be provided in the event of a medical problem.

How will your privacy and confidentiality be protected if you participate in this research study?

You will be assigned a unique *Subject ID* code, which will *only* be identified with your name on this Informed Consent Form. The Health History Questionnaire will not contain any personally identifying information. If for some reason, you are found to be ineligible to participate because you do not meet all of the inclusion criteria, all of your screening data and any other identifiable information will be destroyed. These two forms and this Informed Consent Form will be stored in a locked file cabinet inside a locked office. In all other cases, electronic data will only be identifiable by your unique *Subject ID* code. Only the director of the project (Dr. Dingwell) will have access to a master list that will link your identity to your code. The electronic data will be stored on DVD media and also kept in a locked file cabinet in Dr. Dingwell's office. These data will only contain fully de-identified, non-sensitive information and will be maintained indefinitely.

The records of this study will be stored securely and kept confidential. Authorized persons from The University of Texas at Austin and members of the University of Texas Institutional Review Board, have the legal right to review your research records and will protect the confidentiality of those records to the extent permitted by law. Throughout the study, the researchers will notify you of new information that may become available and that might affect your decision to remain in the study.

If in the unlikely event it becomes necessary for the Institutional Review Board to review your research records, then the University of Texas at Austin will protect the confidentiality of those records to the extent permitted by law. Your research records will not be released without your consent unless required by law or a court order. The data resulting from your participation may be made available to other researchers in the future for research purposes not detailed within this consent form. In these cases, the data will contain no identifying information that could associate you with it, or with your participation in any study. If the results of this research are published or presented at scientific meetings, your identity will not be disclosed.

If you choose to participate in this study, you may choose to be video recorded or photographed. All recordings will be stored securely and only the research team will have access to the recordings. Recordings will be kept indefinitely.

Whom to contact with questions about the study?

Prior, during or after your participation, you can contact the researcher - Dr. Jonathan Dingwell at 512-232-1782 or send an email to jdingwell@austin.utexas.edu. This study has been reviewed and approved by The University Institutional Review Board and the study number is IRB # 2015-03-0038.

Whom to contact with questions concerning your rights as a research participant?

For questions about your rights or any dissatisfaction with any part of this study, you can contact, anonymously if you wish, the Institutional Review Board by phone at (512) 471-8871 or email at orsc@uts.cc.utexas.edu.

Participation

If you agree to participate, sign and return the form to the investigator. You will receive a copy of this form.

Signature

You have been informed about this study's purpose, procedures, possible benefits and risks, and you have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time. You voluntarily agree to participate in this study. By signing this form, you are not waiving any of your legal rights.

____

Printed Name

____ ______________

Signature of Participant Date

As a representative of this study, I have explained the purpose, procedures, benefits, and the risks involved in this research study.

____

Print Name of Person obtaining consent

____ ______________

Signature of Person Obtaining Consent Date

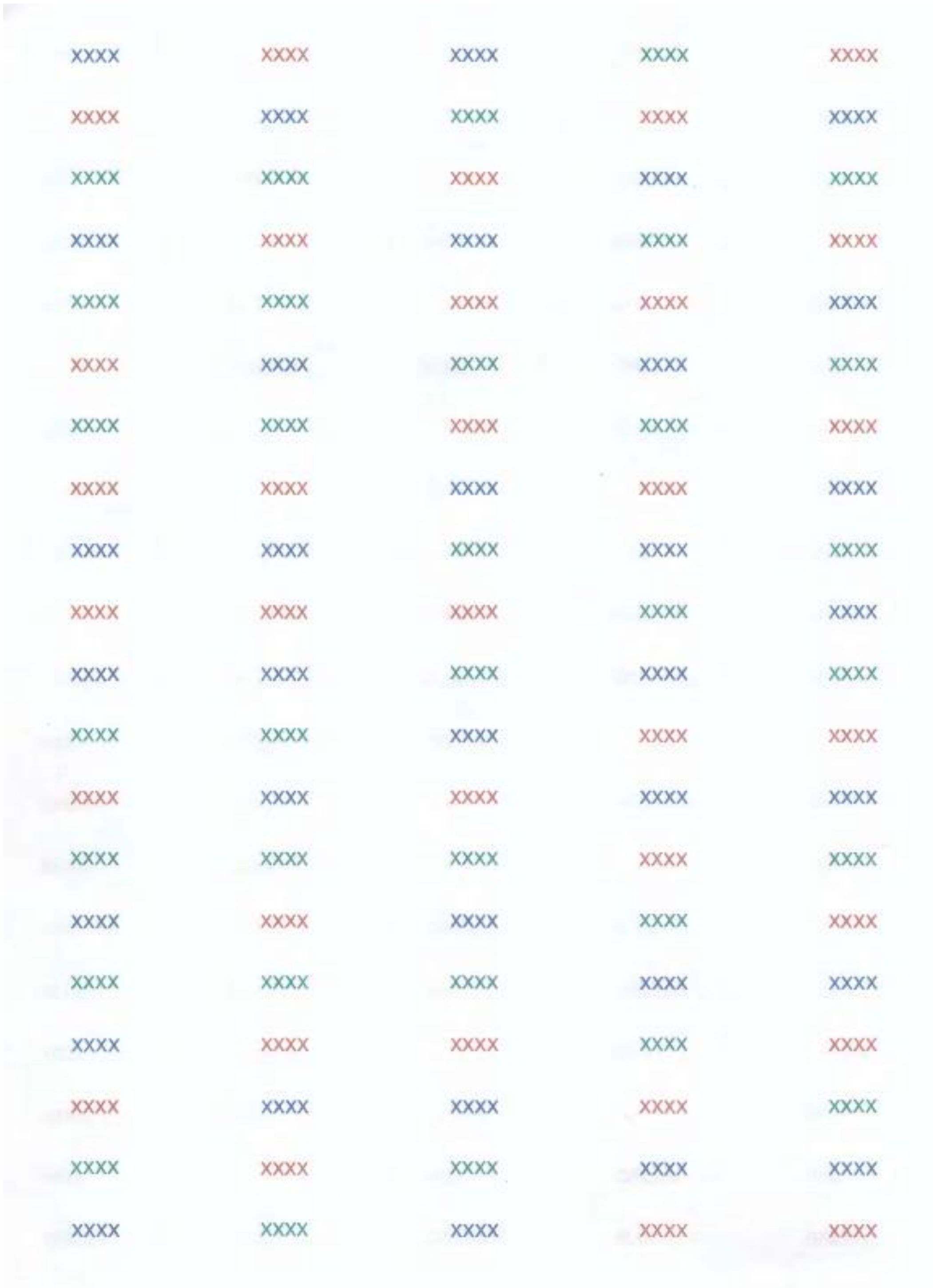
Photograph / Videotape Consent:

As a part of your participation as a volunteer in this scientific research investigation, you may be photographed or videotaped during the course of this experiment. Any photographs and/or videotapes of your performance (without your name or likeness revealed) may be shown to educational audiences, such as scientific conferences. Your consent to be photographed or videotaped is independent of your consent to participate in this investigation. If you have any questions about this consent, you can contact Jonathan Dingwell at (512) 232-1782. By signing below, you hereby give permission for any photographs or videotapes made during the course of this research study to be also used for educational purposes.

Signature of Participant Date

Signature of Person Obtaining Consent Date

APPENDIX D – COLOR BLINDNESS TEST SHEET



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APPENDIX E – HEALTH HISTORY QUESTIONNAIRE AND PHYSICAL ACTIVITY SURVEY

HEALTH HISTORY QUESTIONNAIRE

"Walking Balance While Texting on Cell Phones"

IRB # ***2015-03-0038*** ________ ***Subject ID:*** ______________

Date of Birth (mm/dd/yy): __________________________ Age: ______ ____________

MALE: ______ FEMALE: ______

Height:____________ ft./in.

Weight: ____________ lbs.

BMI (kg/m^2): ____________ [To be completed by researcher]

---

1. Are you taking any medications on a regular basis? (Exclusions include: Psychotropics, Antihistamines, Asthma Meds, Aldomet, Clonidine, Anti-Depressants, Anti-Anxiety Meds) Y / N

2. Any over- the -counter meds? Y / N
   If yes, explain:

3. Do you have any disability or impairment that affects you when you walk? Y / N

4. Have you had any broken bones, surgery, or injury to lower extremities? Y / N
If yes, explain:

5. Do you have arthritis? Does it cause pain or discomfort when you stand or walk? Y / N
If yes, explain:

6. Have you had any significant medical problems within the last 10 years? Y / N
If yes, explain:

7. Do you have a history of neurological diseases likely to affect your ability to stand or walk, including CVA (stroke), disc disease, peripheral neuropathy, or lower extremity weakness? Y / N
If yes, explain:

8. Do you have any history of back problems, such as low back pain? Y / N
If yes, explain:

9. Do you have any problems with standing balance? Y / N
If yes, explain:

10. Do you have any drug and/or alcohol dependence? Y / N

11. Do you have any significant visual impairments? Y / N
Examples: loss of binocular vision or the presence of double vision
If yes, explain:

12. Do you have any heart problems or coronary artery disease? Y / N

13. Do you have hypertension? Y / N

14. Do you have any lung or respiratory problems? Y / N

15. Do you smoke? Y / N
Pattern?:

16. Do you use alcohol? Y / N
Pattern?:

17. Do you use caffeine (cola, coffee, etc.)? Y / N
Pattern?:

18. Do you have any allergies that require medication? Y / N
If yes, explain::

19. Have you fallen during the past year? Y / N

If yes, explain how the fall occurred and what injuries (if any) resulted.

Please also complete Physical Activity Information on the following pages…

Physical Activity: Please fill out the following 3 sections: **Work, Sport, and Leisure**

Work Section:

Question	**Response**	**Points**
What is your main occupation?	Low Activity Moderate Activity High Activity	1 3 5
At work I sit:	Never Seldom Sometimes Often Always	1 2 3 4 5
At work I stand	Never Seldom Sometimes Often Always	1 2 3 4 5
At work I walk	Never Seldom Sometimes Often Always	1 2 3 4 5

At work I lift heavy loads	Never Seldom Sometimes Often Always	1 2 3 4 5
After working I am tired	Very Often Often Sometimes Seldom Never	5 4 3 2 1
At work I sweat	Very Often Often Sometimes Seldom Never	5 4 3 2 1
In comparison of others of my own age I think my work is physically	Much Heavier Heavier As heavy Lighter Much Lighter	5 4 3 2 1

Sport Section:

Question	Response	Points
Do you play sports?	If Yes -- Continue to Sport Part I.	-
	If No -- Continue to “Leisure Section”	-

Sport Part I.

Question	Response	Points
In comparison with others of my own age I think my physical activity during leisure time is	Much More More The Same Less Much Less	5 4 3 2 1
During leisure time I sweat	Very Often Often Sometimes Seldom Never	5 4 3 2 1
During leisure time, I play sport	Never Seldom Sometimes Often Very Often	1 2 3 4 5

Sport Part II.

Question	**Response**	**Points**
What sport do you play most frequently?	Low Intensity Medium Intensity High Intensity	0.76 1.26 1.76
How many hours do you play a week?	< 1 Hour 1-2 Hours 2-3 Hours 3-4 Hours > 4 Hours	0.5 1.5 2.5 3.5 4.5
How many months do you play in a year?	< 1 Month 1-3 Months 4-6 Months 7-9 Months > 9 Months	0.04 0.17 0.42 0.67 0.92

Leisure Section:

Question	**Response**	**Points**
During leisure time I watch television	Never Seldom Sometimes Often Very Often	1 2 3 4 5

During leisure time I walk	Never Seldom Sometimes Often Very Often	1 2 3 4 5
During leisure time I cycle	Never Seldom Sometimes Often Very Often	1 2 3 4 5
How many minutes do you walk and/or cycle per day to and from work school and shopping?	< 5 minutes 5-15 minutes 15-30 minutes 30-45 minutes > 45 minutes	1 2 3 4 5

Final Total Score: ______________

(To be completed by researcher)

APPENDIX F – CELL PHONE USAGE QUESTIONNAIRE

CELL PHONE USAGE QUESTIONNAIRE

"Walking Balance While Texting on Cell Phones"

IRB # 2015-03-0038 ***Subject ID:*** ______________

Which type of phone do you use?	○ iPhone ○ Other touch screen phone
For how long have you been using a touch screen (smart) phone?	______ Months
About how many texts do you send per day (weekday)?	○ 0-9 ○ 10-30 ○ 31-50 ○ 51-70 ○ 71-90 ○ 91-110 ○ >110
Which hand do you most often use to type text?	○ Left ○ Right ○ Both
While typing text how do you most often orient cell phone?	○ Landscape ○ Portrait
About how often do you use cell phone while walking?	○ Always ○ Very often ○ Rarely ○ Never
Time spent in *reading* text and/or email on cell phone while walking	_______ %
Time spent *typing* text and/or email on cell phone while walking	_______ %
Time spent playing interactive *games* on cell phone while walking	_______ %
Time spent *talking* on cell phone while walking	_______ %

Time spent *listening* music on cell phone while walking	_______ %
Time spent in performing *other task* (e.g. navigating, watching video) on cell phone while walking	_______ %
Have you ever experience collision or near collision while texting and walking?	○ Yes ○ No

Appendix G – Handedness assessment

Handedness Assessment

[Modified Edinburgh Inventory (Oldfield 1971)]

IRB #: _*2015-03-0038*___________ **Subject ID: ____________________**

Which hand do you ***_**usually**_*** use to….

1. Brush your teeth? R ________ L ________
2. Shave? R ________ L ________
3. Write? R ________ L ________
4. Move a computer mouse? R ________ L ________
5. Hold on top while using a broom? R ________ L ________
6. Hold your knife while cutting food? R ________ L ________
7. Throw a ball? R ________ L ________
8. Cut with scissors? R ________ L ________
9. Strike a match? R ________ L ________
10. Draw? R ________ L ________

Total: R ________ L ________

NOTE: Questionnaire based on:

Oldfield RC. “The Assessment and Analysis of Handedness: the Edinburgh Inventory,” *Neuropsychologia* **9**(1): 97–113, 1971.

APPENDIX H – SUBJECT DATA FORM

SUBJECT DATA FORM

"Walking Balance While Texting on Cell Phones"

√	Checklist	
Consent and Screening:		
☐	Explain experimental protocol to participant. Have participant read consent form. Answer any/all questions participant might have.	
☐	Participant signs consent form if willing.	
☐	Participant fills out *Health History Questionnaire*	
☐	Participant fill out *Cell Phone Usage Survey*	
☐	Participant fill out *Handedness Survey*	
☐	Participant completes *Visual Color Discrimination Test*	
☐	Baseline Cognitive Assessment: Participant completes *Wisconsin Card Sorting Test*	
☐	Baseline Cognitive Assessment: Participant completes *Kaufman Brief Intelligence Test*	
☐	Baseline Cognitive Assessment: Participant completes *Attention Span Survey*	
Calibrate VICON System:		
☐	1. Power system on 2. Aim cameras 3. Create Camera Masks 4. Calibrate Cameras with wand 5. Set Camera origin 6. Create subject 7. Marker Subject 8. Subject Calibration	
Subject Measurements:		
☐	Body Mass	___________ kg
☐	Height	___________ m
☐	Age	___________ yrs
☐	Sex	____ Male or ____ Female
☐	Leg Length: greater trochanter to the floor	___________ m
☐	Dominant leg: Which foot do you kick a soccer ball with?	____ Right or ____ Left
☐	Physical Activity Score: Calculate from HHQ	___________ Points
Calculate Normalized Walking Speed:		

☐	Compute speed based on Froude number of 0.16: $v_w = \sqrt{f_r \cdot g \cdot l} = \sqrt{0.16 \cdot 9.81 \frac{m}{s^2} \cdot (\_\_\_\_\_\_\_\_\_\_ \ m)}$ Gives answer in m/s, to convert to mph: $v_w = \_\_\_\_\_\_\_\_\_\_ \ \frac{m}{s} \times (2.2369) \ = \_\_\_\_\_\_\_\_\_\_ \ mph$	________ m/s	________ mph

Prepare Participant for Data Collection:

☐	Place HARNESS and reflective markers on Participant.
☐	Reiterate experimental protocol to Participant.
☐	Participant performs cell phone task while seated (5-10 min): Baseline Score =
☐	Collect STATIC trial of participant on treadmill.
☐	Participant walks on Treadmill for acclimation (5-10 min).

Order in Which to Present Conditions to Each Participant:

[Counter-Balanced Measures (Latin Square) Design]

Conditions:
NN = No Text + No Obstacle Avoidance
NS = No Text + Simple Obstacle Avoidance
NC = No Text + Complex Obstacle Avoidance
TN = Texting + No Obstacle Avoidance
TS = Texting + Simple Obstacle Avoidance
TC = Texting + Complex Obstacle Avoidance

Subj #				
1	7	13	19	25
2	8	14	20	26
3	9	15	21	27
4	10	16	22	28
5	11	17	23	29
6	12	18	24	30

Trial #											
1	2	3	4	5	6	7	8	9	10	11	12
NN	NS	TC	NC	TS	TN	NC	TN	NS	TS	NN	TC
NS	NC	NN	TN	TC	TS	TN	TS	NC	TC	NS	NN
NC	TN	NS	TS	NN	TC	TS	TC	TN	NN	NC	NS
TN	TS	NC	TC	NS	NN	TC	NN	TS	NS	TN	NC
TS	TC	TN	NN	NC	NS	NN	NS	TC	NC	TS	TN
TC	NS	TS	NS	TN	NC	NS	NC	NN	TN	TC	TS

Trial Comments:

Trial	Condition	Comments:
1		
2		
3		
4		
5		

6		
7		
8		
9		
10		
11		
12		

Appendix I – Order of presentation of trials

Order in Which to Present Conditions to Each Participant:

[Counter-Balanced Measures (Latin Square) Design]

Conditions: NN = No Text + No Obstacle Avoidance
NS = No Text + Simple Obstacle Avoidance
NC = No Text + Complex Obstacle Avoidance
TN = Texting + No Obstacle Avoidance
TS = Texting + Simple Obstacle Avoidance
TC = Texting + Complex Obstacle Avoidance

Subj #					Trial #											
					1	2	3	4	5	6	7	8	9	10	11	12
1	7	13	19	25	NN	NS	TC	NC	TS	TN	NC	TN	NS	TS	NN	TC
2	8	14	20	26	NS	NC	NN	TN	TC	TS	TN	TS	NC	TC	NS	NN
3	9	15	21	27	NC	TN	NS	TS	NN	TC	TS	TC	TN	NN	NC	NS
4	10	16	22	28	TN	TS	NC	TC	NS	NN	TC	NN	TS	NS	TN	NC
5	11	17	23	29	TS	TC	TN	NN	NC	NS	NN	NS	TC	NC	TS	TN
6	12	18	24	30	TC	NS	TS	NS	TN	NC	NS	NC	NN	TN	TC	TS

APPENDIX J – FINAL COGNITIVE VARIABLES

Test Name	Variable Definition	Variable Name
KBIT 2 - Kaufman Brief Intelligence Test (second edition)	IQ score	KBIT_Composite
PPVT- PEBL Perceptual Vigilance Task	Mean of Reaction Time	PPVT_avg
	Standard deviation of Reaction Time	PPVT_sd
	Accuracy	PPVT_accuracy
	Mean 1/Reaction Time	PPVT_ Mean1overRT
BCST- Berg's Card Sorting Test (i.e. PEBL version of Wisconsin CST)	Incorrect response which would have been correct for previous rule.	BCST_PE
	Number of correct and incorrect responses which are perseverative	BCST_PR
	The number of times five or more consecutive correct responses occur without completing the category.	BCST_FMS
	The number of runs of 10 correct responses	BCST_Categories_Completed
	Mean of Reaction Times	BCST_avg
Go-NO Go Test	Absence of response to a target	GNG_Omission_Error
	Error associated with response to false alarm	GNG_Commission_Error
	Mean of Reaction Time	GNG_avg
	Standard Deviation of Reaction Time	GNG_sd

The above mentioned 14 outcome variables are those that are generally reported by studies involving these cognitive tests.

Some of the variables were removed from analysis.

Variable removed from further analysis	Reason
PPVT_Accuracy	Ceiling effect - almost half of the participants were 100% accurate, due to the simplicity of the task.
PPVT_mean1overRT	Similar data was represented by PPVT_avg. PPVT_avg and PPVT_mean1overRT were highly correlated.

The final (reduced) variables which were not correlated to each other were used.

Appendix K – Cognitive test statistics

Descriptive Statistics

	N	Mean	Std. Deviation
KBIT_Composite	30	101.2000	11.41203
PPVT_avg	30	336.0337	39.53315
PPVT_sd	30	44.9313	10.48625
BCST_PE	30	11.8837	5.10420
BCST_PR	30	32.4733	4.91411
BCST_FMS	30	1.1667	1.34121
BCST_Categories_Completed	30	8.0667	1.79911
BCST_avg	30	1218.1443	284.86770
GNG_Commission_Error	29	4.3793	2.48443
GNG_Omission_Error	29	.3103	.71231
GNG_avg	29	480.7293	30.85762
GNG_sd	29	76.8579	18.02897

APPENDIX L – LINEAR CORRELATION ANALYSES OF COGNITIVE VARIABLES WITH CELL PHONE AND OBSTACLE AVOIDANCE TASK PERFORMANCE

		PPVT_Avg	PPVT_SD	Perseverative_Error	Perseverative_Response	FMS	Categories_completed	BCST_Avg_ALL	Omission_error	Commission_error	GNG_Avg_All	GNG_SD_All	BMI
TC_Per_Collision	Pearson Correlation	.379*	.040	-.045	.020	.427*	-.116	-.205	.021	.141	-.116	.056	-.223
	Sig. (2-tailed)	.039	.835	.813	.918	.019	.542	.278	.914	.456	.550	.772	.235
TS_Per_Collision	Pearson Correlation	.431*	.208	-.198	.002	.642**	-.020	-.039	.099	-.161	-.085	.004	-.344
	Sig. (2-tailed)	.017	.271	.294	.992	.000	.914	.837	.603	.395	.661	.982	.063
NC_Per_Collision	Pearson Correlation	.136	.028	.036	.023	.067	.137	.152	.233	.355	-.241	.053	.029
	Sig. (2-tailed)	.475	.884	.852	.904	.725	.472	.421	.214	.055	.207	.785	.879
NS_Per_Collision	Pearson Correlation	.356	.270	-.171	-.115	.387*	-.032	.195	-.094	-.015	-.027	.124	-.306
	Sig. (2-tailed)	.053	.149	.366	.544	.034	.865	.301	.620	.937	.891	.522	.100
TC_Avg_MT	Pearson Correlation	.283	.414*	.017	-.060	.066	.033	.129	.284	-.076	.354	.120	-.081
	Sig. (2-tailed)	.129	.023	.929	.751	.730	.862	.496	.128	.690	.059	.536	.671
TS_Avg_MT	Pearson Correlation	.320	.267	.091	.182	.374*	-.128	-.088	.121	.212	-.045	.262	.138
	Sig. (2-tailed)	.085	.154	.633	.335	.042	.501	.642	.526	.260	.816	.170	.466
NC_Avg_MT	Pearson Correlation	.258	.175	.066	.206	.134	-.115	.056	.030	.059	-.051	.305	.051
	Sig. (2-tailed)	.169	.356	.727	.276	.481	.544	.767	.876	.759	.792	.108	.787
NS_Avg_MT	Pearson Correlation	.212	.118	-.042	.223	.342	-.113	.032	.130	.232	-.263	.271	.049
	Sig. (2-tailed)	.260	.534	.825	.236	.065	.552	.869	.494	.217	.168	.155	.799
TC_SD	Pearson Correlation	-.184	-.036	.149	.127	-.291	.338	.375*	-.267	.038	-.223	-.108	-.070
	Sig. (2-tailed)	.331	.849	.432	.505	.118	.068	.041	.153	.843	.244	.575	.712
TS_SD	Pearson Correlation	-.019	-.075	.052	-.173	-.086	.015	.448*	.104	-.129	.269	-.090	-.073
	Sig. (2-tailed)	.923	.693	.785	.362	.650	.936	.013	.585	.497	.159	.642	.702
NC_SD	Pearson Correlation	-.097	-.050	.079	.130	.010	.037	.240	-.061	.358	-.421*	.065	.102
	Sig. (2-tailed)	.610	.795	.677	.492	.958	.848	.200	.748	.052	.023	.739	.591
NS_SD	Pearson Correlation	.061	.176	.455*	.285	-.081	-.026	.183	.044	.073	.003	.178	.077
	Sig. (2-tailed)	.748	.351	.012	.127	.669	.893	.333	.816	.702	.986	.356	.685
TC_GS	Pearson Correlation	.115	-.024	-.398*	-.569**	-.080	.358	.053	-.064	-.336	.275	-.318	-.041
	Sig. (2-tailed)	.546	.900	.029	.001	.675	.052	.781	.736	.069	.149	.093	.828
TS_GS	Pearson Correlation	-.011	-.089	-.462*	-.642**	-.147	.337	-.092	-.099	-.255	.176	-.370*	-.039
	Sig. (2-tailed)	.953	.640	.010	.000	.437	.069	.630	.601	.175	.360	.048	.837
TN_GS	Pearson Correlation	-.002	-.020	-.349	-.332	-.098	.312	-.011	-.087	-.166	.006	-.159	-.057
	Sig. (2-tailed)	.991	.918	.059	.073	.608	.093	.954	.649	.382	.974	.411	.764

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