Research Article

The impact of multitasking on visual processing speed, cognitive inhibition, executive function, and short-term memory

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ABSTRACT

Background: The simultaneous usage of cell phone while driving and reading has become ubiquitous phenomenon which can have detrimental effects. **Objective:** We evaluated the effect of simultaneous cell phone conversation on multiple cognitive domains using standard battery of cognitive tests. **Materials and Methods:** Apparently healthy participants (age 18–25 years) who had no cognitive, visual, motor, and hearing impairments were recruited. They performed visual reaction time (VRT), Go-No-Go (GNG) task, Stroop's task, and N-back test either during a cell phone conversation or without it, in a randomized crossover trial. The difference in latency was analyzed using Wilcoxon Signed-Ranked test among the paired data which were not normally distributed, while paired *t*-test was used for the normally distributed data. McNemar test was used to find the accuracy of the responses for all the four tasks. **Results:** The latency of the VRT, GNG, and Stoop's test significantly increased while using the cell phone compared to without using a cell phone ($P < 0.001$). N-back test had a similar trend though not statistically significant. Accuracy reduced during the cell phone conversation in VRT ($P < 0.004$), Stroop's test ($P < 0.001$), and N-back test ($P < 0.013$). GNG did not show a statistically significant reduction in accuracy. **Conclusions:** There is reduction in specific cognitive abilities (both in latency and accuracy) during multitasking, for instance, reaction time and executive function while conversing through a mobile phone.

KEY WORDS: Cognition; Mobile Phone; Multitasking; Reaction Time; Stroop's Test

INTRODUCTION

People often perform more than one task without conscious awareness, when each task has its own goal and stimulus-response associations, for instance, attending to children while cooking, handling multiple projects, at the same time, although seems time saving, has its detrimental effects. Although people perform multitasking, the performance reduces in both the tasks due to dual task interference.[1] It is evident that though the human brain is remarkably flexible, its cognitive information processing speed is severely limited in capacity due to the available resources.[2] However, individual performance in multitasking depends on the age,[3] working memory capacity-limitation, nature of the tasks, personality traits, and the previous experience in the tasks.[4] One of the most common multitasking people involve nowadays is conversing through a cell phone while engaging in other activities such as driving and reading. The drivers who were conversing, either handheld, or hands-free mode, performed poor in driving speed, following distance, reaction time while braking and involved in more traffic accidents compared to

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not using the cell phone as well as after consuming alcohol within legal limits.[5] This dual tasking of driving while using cell phone shows minimal improvement due to practice.[6] The driving performance reduces even after the cessation of the usage of cell phone due to the residual cognitive load.[7] These results summaries that driving impairment while conversing through a cell phone is purely cognitive not peripheral. These studies imply that reaction time and decision-making time is deranged with simultaneous usage of cell phone. Delay in reaction time indicates poor attention and errors in decision-making indicate reduced executive function. Hence, it is evident these cognitive domains are impaired during multitasking such as simultaneous cell phone usage. The other recent problem for the present millennial students is multitasking while learning and reading, such as using Facebook and texting.[8] Simultaneous smartphone usage severely impact gait and it implies the detrimental effects on cognitive load and reduction in attention.[9] Usage of cell phone can destabilize the information-processing and can cause attention failure of the primary task.[10] The cognitive impairment due to the simultaneous usage of mobile phone is primarily due to the cognitive load and not due to the radiation,[11] although, detrimental effects of radiation are demonstrated to have negative epigenetic effect on the neurodevelopment of children.[12] The cognitive decline in various domains such as reaction time, choice inhibition, and executive function due to long-term mobile phone usage was evident among the school-going children.[13] Overhearing to someone talking through cell phone (halfalog) can cause reduction in cognitive domains like choice reaction time.[14] Hence, it is evident multitasking, although our everyday life, reduces various cognitive domains. However, quantifiable data on the effects of simultaneous usage of mobile phone on cognitive domains such as visual processing speed, selective inhibition, decision-making, executive function, and short-term memory are sparse among the Indian college going adolescences. Therefore, the study was designed to evaluate the effect of everyday multitasking, cell phone usage, on the above cognitive domains.

MATERIALS AND METHODS

The institutional ethic committee approval was obtained for the study IEC:RC/14/133. Apparently healthy adults of the age 18–25 years (n = 101, females = 26) without any cognitive, motor, visual, and hearing defects were recruited. The study protocol was explained to them in detail and they gave their written informed consent. The study was conducted during the months of June till July - 2015 in the Department of Physiology, Pondicherry Institute of Medical Sciences (PIMS), Pondicherry, after 4 PM till 6 PM. All participants were from PIMS. The participants familiarized with the laboratory and trained in the cognitive tests which were presented to them on a desktop using Cedrus Superlab Pro 5 stimulus presentation software (Cedrus corporation, San Pedro, CA, USA). The subjects responded using a response pad. The desktop was placed at a convenient reading distance of 1 m from the participants and the response pad was placed on the table. The participants placed both their hands on either side of the response pad, and they were allowed to use both their hands to respond. The participants used their own cell phone for the study purpose. To overcome the Hawthornean (practice) effect, the tasks were administered in two randomized blocks. In Block A, the cognitive tasks were done without using a cell phone first followed by while using the mobile phone in hands-free mode and in Block B the same tasks were performed while the subject was conversing through a mobile in the hands-free mode first followed by without cell phone. The order of the block was prior randomized to each participant. During the mobile phone conversation, the subjects were questioned on a similar set of questions prepared beforehand on topics pertaining to their schooling, friends, hobbies, and places visited. The response accuracy (number of trials answered correctly) and latency of the cognitive tasks were collected. The followings were the cognitive tests which were performed. All the stimulus were presented for 1000 ms duration.

Visual Reaction Time (VRT)

VRT is the measure of visual processing speed and visual attention. The subject had to respond to a visual stimulus (a green colored dot) by pressing the central response button as fast as possible. A total of six trials were administered. If they responded to the stimuli within the stipulated time of 1000 ms, then it was recorded as a correct response (C). The average latency of all correct responses (Cs) was taken as reaction time. All six stimuli should be Cs to consider the participant as correct responder compared to non-responder for accuracy calculation.

Go-No-Go (GNG) Task

This test evaluates for selective attention or choice attention and cognitive inhibition. The subject had to respond to green visual stimuli by pressing the central response button as fast as possible and withhold the response to the red visual stimuli. Total of 13 stimuli were presented. The average latency of the correct responses was taken as reaction time. When the subject responded appropriately to all 13 stimuli, then it is taken as a correct responder to calculate for accuracy.

Stroop Task

This test evaluates the executive function. A colored word, for instance, "RED," would appear on the screen in a different ink color, in "GREEN INK." The subject had to respond to either to the meaning of the written word (red) or to the ink color (green) neglecting the meaning of the word, by pressing the appropriate colored button on the response pad as fast as possible, in two different type of tasks. The first initial

12 trials were presented for the Stroop word task, and then 12 for the ink color, Stroop color task, and making it a total of 24 trials. The average time for the correct responses was noted as reaction time. When all 24 trials were responded appropriately, then it was considered as correct responder for calculating the accuracy.

N-back Task

This test evaluates short-term memory. If the presenting stimulus matches with the stimulus presented two stimuli earlier, then the subject had to respond by pressing the central button (white color) on the response as fast as possible (e.g., A, F, and A). In a single trial 38 such stimuli were given to the subject. If the subject answered 30 or more stimuli correctly (the number was based on the median value of responses from the control), then it is considered as a correct responder. The average latency of all the correct responses was noted as reaction time.

Statistical Analysis

Descriptive statistics are expressed as mean and standard deviation for normally distributed data and as median and interquartile range for data which are not normally distributed. Wilcoxon signed-ranked test was used to find the differences between the latency among the paired data which were not normally distributed, while paired *t*-test was used for the normally distributed data. McNemar test was used to find the accuracy of the responses for all the four tasks. Statistical significance was kept at $P < 0.05$ and all tests were two sided. The data were analyzed using SPSS version 20.0.

RESULTS

The median or the mean reaction time of all the cognitive tests was significantly higher during the cell phone conversation compare to control, although N-back test had a similar trend without statistical significance. The accuracy was significantly lower for all tests during cell phone usage compared to control, except for the GNG task although it had a similar trend.

VRT

Median reaction time during mobile phone conversation was 506 (435.6–577.7) ms, which was significantly higher than the median reaction time without using the mobile 378.8 (337.4–447.6) ms, ($P < 0.001$). From the total 101 subjects, 99 answered without errors in control group to all the six trials while only 87 subjects answered correctly during mobile conversation, which was found to be statistically significant using McNemar test ($P = 0.004$) [Table 1].

GNG Task

Median reaction time during mobile phone conversation was 522.2 (459.7–632) ms, which was significantly higher than the median reaction time of the controls 461.6 (416–534.7) ms, ($P < 0.001$). 76 of the subjects answered, all the 13 trials correctly in the control group while 72 answered correctly among the test group, and the difference was statistically insignificant based on McNemar test ($P = 0.7$) [Table 1].

Stroop Task

Mean reaction time during mobile phone conversation was 1241.8 ± 141.5 ms which was significantly higher than the mean reaction time of controls 1102.3 ± 164.1 ms, for performing the Stroop task ($P < 0.001$). Thirty-one answered, all the 24 trials correctly in the control group and ten answered correctly during the mobile phone usage trial, which was found to be statistically significant using McNemar test ($P < 0.001$) [Table 1].

N-back Task

Median reaction time during mobile phone conversation was 704 (572.9–841.2) ms which was not significantly higher than the mean reaction time of controls 644.3 (537–788) ms, ($P = 0.07$). Ninety-two participants in the control group were responder while 81 managed to be responders (as per our criteria) in the mobile phone group, which was found to be statistically significant using McNemar test ($P < 0.013$) [Table 1].

DISCUSSION

Summary

Our study results elucidated detrimental effects in latency and accuracy of all the cognitive domains tested due to simultaneous usage of cell phone, although not statistically significant in some cognitive domains. Hence, it is evident that multitasking can have a detrimental effect in visual

Table 1: Comparison of within subject change in latency in milliseconds while using cell phone and while not using cell phone

Test performed	Latency without using cell phone (ms)	Latency while using cell phone (ms)	*P*-value
VRT©	378.8 (337.4–447.6)	506 (435.6–577.7)	<0.001*
GNG task©	461.6 (416–534.7)	522.2 (459.7–632)	<0.001*
Stroop task#	1102.3±164.1	1241.8±141.5	<0.001‡
N back test©	644.3 (537–788)	704 (572.9–841.2)	=0.07*

©Data expressed as median and inter quartile range. #Data expressed as mean and standard deviation. VRT: Visual reaction time, GNG: Go-no-go, **P*-value obtained using Wilcoxon signed-ranked test. ‡*P*-value obtained using paired *t*-test

processing speed, attention, cognitive inhibition, decision-making, and executive function and short-term memory.

The VRT elucidated that median reaction time increased during cell phone conversation. This reaction time increment is not due to the auditory distraction[15] but may be due to the cognitive load of conversing. Talking through cell phone alone without taking the visual attention from the road may not lead to road traffic accidents (RTAs),[16] since the drivers increase their cognitive arousal, stabilize their gaze in a naturalistic traffic.[17] However, increased reaction time may be attributed as the primary cause of RTAs apart from other factor such as bad roads and difficult terrains.[18] Therefore, further studies are needed to evaluate the impact of cell phone conversation on RTAs. Since attention allocation is the key for memory, lack of attention can lead to memory impairment[19] and learning. Exposure of short-term mobile phone radiation does not cause decline in memory;[20] therefore, it is evident that the cognitive load of using cell phone (multitasking) leads to memory impairment. In our study, the GNG task was designed with rare No-Go trials and shorter trial duration thereby there is a prepotent response followed by inhibition.[21] The primary cognitive domain assessed by GNG is the prefrontal circuits which modulates behavioral inhibition.[22,23] This cognitive inhibition can be evaluated by the accuracy of not pressing the No-Go signal and our results did not show statistically significant difference while multitasking. However, the reaction time of the GNG task increased significantly while using the cell phone compared to control reflecting reduced visual attention allocation due to multitasking which can have detrimental effect on memory as mentioned earlier. The mean reaction time of the Stroop's test increased while using mobile phone compared to control which indicates delay in attention during simultaneous usage of cell phone[24] and reduced function of the left dorsolateral prefrontal cortex which is involved in behavioral control.[25] Our data were analyzed after pooling both the congruent and incongruent Stroop tests for reaction time and accuracy. During the cell phone usage, only ten of the participants were able to answer all the test correctly compared to 24 during control. The Stroop test is traditionally used in neuropsychology to test executive function including selective attention, cognitive flexibility, and cognitive inhibition[26-28] which are the functions of inferior frontal, dorsolateral prefrontal, and anterior cingulate cortices.[29] Hence, executive function involves the behavioral traits necessary for learning and memory and our Stroop test data elucidated that multitasking would negatively influence it. N-back test assesses the working memory which is a function of the prefrontal cortex.[30] Our study data elicited that the N-back accuracy was reduced, and the latency also increased although not statistically significant, reflecting reduced executive working memory. The decrement in all cognitive domains both in latency and accuracy as reflected by the results of our study can be explained due to the cognitive resource limitation, or due to interference of the dual task at various cognitive levels of processing or due to the threaded cognitive theory model.[31]

Limitation

Cognitive domains like memory, executive function has many other physiological influences such as the natural intellect and the motivation of the subject which is not considered in the present study.

CONCLUSION

Our study has quantified the decrement in cognitive performance during concurrent mobile phone usage. Our results demonstrated that the subjects were slower and less accurate during mobile phone usage. These results can be used to create awareness on mobile phone usage during simultaneous activities (e.g., driving, and listening to lecture) especially among the educated community.

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