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# The Effect of Hands-Free Cell Phone Conversation on Psychomotor Performance Required for Safe Driving: A Quasi-Experimental Study

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## Abstract

**Background:** Hands-free cell phone conversation (HFCC) while driving is a common practice among drivers. Several studies have revealed that HFCC, while driving, is no safer than hand-held cell phone conversations (HHCC). This study was conducted to explore the influence of HFCC on the psychomotor performance of drivers.
**Methods:** In this quasi-experimental study, the participants were randomly allocated into 2 groups. Participants in group1 passed the traffic psychological battery of the Vienna test system (VTS) once without being engaged in any phone conversation and again while making a HFCC. The order of testing in the 2nd group was reversed. All participants shifted their group and passed the tests in a reverse order after 7 to 10 days. The tests included peripheral perception, perceptual speed, general intelligence, visuomotor coordination, and time anticipation. The mixed model analysis was used to assess the association of HFCC with every test.
**Results:** A total of 24 students, with a mean age of 27.1 ± 5.3 years, were included in the study. HFCC had a significant negative influence on the overall mean duration (P value = 0.015), overall percent error duration (P value < 0.001) in visuomotor coordination median deviation time (P value = 0.007) in time anticipation, divided attention in peripheral perception test (P value = 0.053), and general intelligence (P value = 0.005). However, perceptual speed and field of vision did not reveal any significant association.
**Conclusions:** These findings provided further evidence of the adverse effects of HFCC during driving. Even though drivers can perceive an obstacle while talking on a hands-free cell phone, they are highly likely to react incorrectly due to impairment of visuomotor coordination, time anticipation, divided attention, and fluid intelligence.

*Keywords:* Driving, Hands- Free Cell Phone, Visuomotor Coordination, Time Anticipation, Intelligence, Selective Attention

## 1. Background

Nearly 85% of adults talk on their cell phones while driving (1). Undoubtedly, one of the important causes of road traffic accidents is using a cell phone while driving (2, 3). For a sample of young drivers, who were involved in an accident in Australia, New Zealand, and Colombia, use of a cell phone was the most important predictor of car crash, followed by driving under the influence of alcohol (4). The distracting effect of cell phone conversation on driving and attention may even exceed the effect of other dual tasks, such as listening, holding the phone, and repeating spoken words (5).

Using hands- free cell phone only removes manual distraction, however, cognitive distraction remains to be a problem (6). Driver distraction is a growing problem in traffic accidents (7) and diverts attention from tasks that are critical for safe driving to a non-driving activity (8). Cell phone conversation creates a form of inattention blindness, in which drivers become unsuccessful to notice information in visual sights (7).

Bans on HHCC have decreased this risky behavior for all drivers in those states that have adopted such legislation (9). When HHCC is banned, drivers tend to use Hands-Free Cell Phone (HFC) (10). In a study done in the Netherlands, 2% of drivers reported using Hand-Held Cell Phone (HHC) vs. 14% who reported using HFC while driving (11). In London, 2.8% of car drivers used HHC vs. 4.8% who used HFC (12).

The use of a hands-free cell phone during driving adversely affects acceleration, lane deviation, reaction time, and accuracy (13). In addition, it causes extended braking time, a smaller amount of time on the target speed (14).

Driving is a complex performance that requires adequate visual, cognitive, and motor skills. Thus, it is highly important that drivers have sufficient attention, reaction time, executive function, visual, and physical function (15).

Currently, the laws related to cell phone use while driving varies from total ban (e.g., in Japan) to prohibition of hand-held cell phone use in several countries. The diversity of the laws indicate the absence of a common understanding about the influence of cell phone use on driving safely (16). Therefore, the present study aimed at further exploring the ways HFCC affects driving performance. We particularly aimed at clarifying the effects of HFCC on peripheral perception, eye-hand coordination, perceptual speed, general intelligence, and time anticipation abilities of drivers.

## 2. Methods

### 2.1. Participants

A total of 24 volunteer students from Tehran University of Medical Sciences, aged 20 to 39 years, were included in the study. Inclusion criteria were having a driver's license and a driving experience of more than 1 year.

### 2.2. Ethical Approval

The research project was approved by the research ethics committee of Tehran University of Medical Sciences (reference: IR TUMS.REC.2015.1984-7/12/2015). All the participants signed an informed consent form. To motivate the participants, they were offered a cash reward based on their test results, which did not exceed $14 per session. At the end of the 3rd session, the reward was paid.

### 2.3. Procedure and Study Tools

This was a prospective crossover quasi-experimental study administered over 3 days during 2016. The participants were briefed about the traffic psychological battery of VTS including cell phone conversation the day before the actual test day.

Participants were randomly divided into 2 groups. In the first trial, those in group 1 took the 5 VTS tests while talking on a cell phone via a simulated hands-free system. After a 60-minute rest, they repeated the same tests without making any phone conversation. Participants in group 2 took the tests in a reverse order, i.e., they did the 1st round of tests without making any phone conversation and the 2nd round with a phone conversation (the 2nd day). In the 2nd trial, all participants shifted to the other group and passed the tests again after 7 to 10 days (the 3rd day). Figure 1 demonstrates the study design.

During the administration of the tests, while making a phone conversation, an observer sat to the left of the participant and broadcasted the questions that had been previously recorded.

VTS traffic psychological test battery was used to measure the psychomotor performance of driving. Drivers are required by law to pass these tests in case of involvement in serious traffic violations and accidents in 25 countries worldwide (17). The validity and reliability of these tests have been approved in previous studies (18, 19). In our study, 5 tests were used as follow:

Two-hand coordination (2 HAND, S3): This test assesses visuomotor coordination. The main variables are overall percent error duration and overall mean duration points. Low score indicates a better performance.

Time-movement anticipation (ZBA, S4): This test measures the participant's ability to estimate the speed and movement of an item in space. The square root of median deviation time is the main variable of this test, and a low score reflects a better performance.

Peripheral perception (PP): This test evaluates peripheral perception. The main variables of this test are field of vision and tracking deviation (divided attention). A high score in visual fields and a low score in tracking deviation indicate better performance.

Adaptive matrices test (AMT, S11): This test measures general intelligences. High score indicates better performance.

Adaptive tachistoscopic traffic perception test (ATAVT, S1): This test measures visual observational ability and perceptual speed. High score reflects better performance.

Hands-Free cell phone conversation task: Conversation dialogs were translated and modified from the Rosenbaum verbal cognitive test battery, created by Gail Rosenbaum. It was neutral and included solving a puzzle (e.g. If you see a picture with a circle to the left of a square but on top of a cross, is the cross a. above the square? b. to the left of the circle? c. below the circle?), repeating a sentence (e.g. The students needed to complete chapters nine and 11 and answer the question on page 20), and talking on a special topic (monologue) (e.g. Describe your last trip) (17).

### 2.4. Statistical Analysis

The tests were repeated 4 times, and we obtained 4 records of tests for each participant, with 2 tests while making a phone conversation and 2 with no phone conversation.

The mixed model analysis was used to look into the association between different VTS tests (as the dependent variable) and the simulated cell phone conversation (as

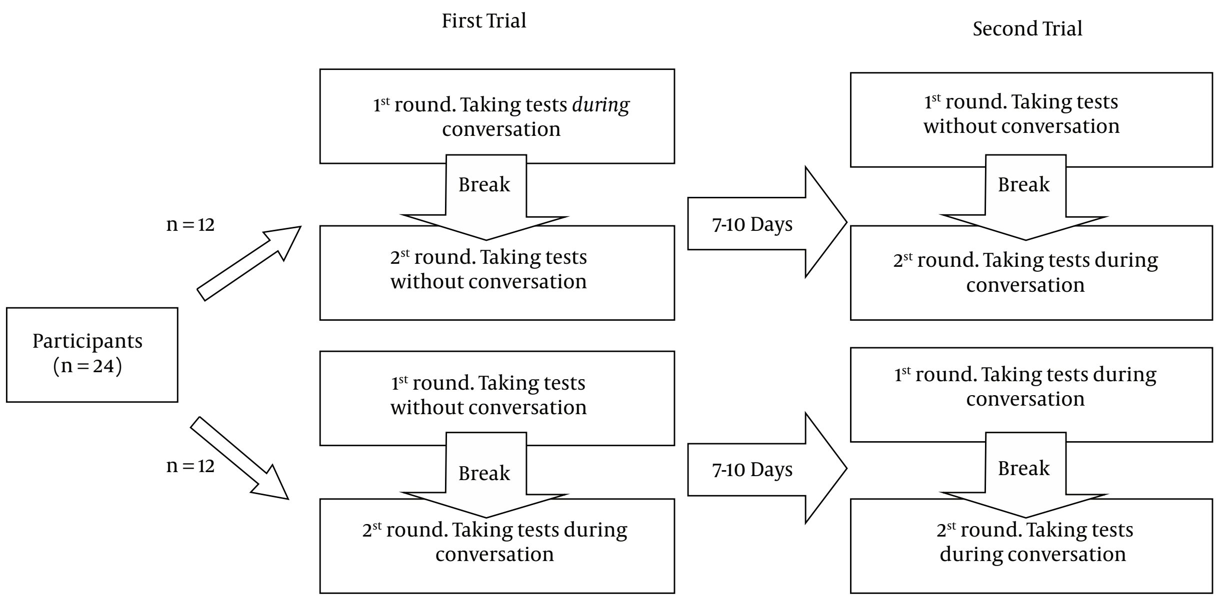


**Figure 1.** The Cross Over Study Design

the independent variable). The effect of the learning curve (due to the repetition of testing) was controlled by including it in the model. All statistical analyses were performed using IBM SPSS statistics software Version 21. Significance level was set at 0.05.

## 3. Results

In this study, 12 male and 12 female students with the mean age of $26.3 \pm 4.6$ and $27.9 \pm 5.7$, respectively, were included. No statistically significant differences were observed in the age of male and female participants ($P > 0.05$). All participants had cell phones and used them at least once during the preceding year while driving, 3 participants (12.5%) felt that the simulated conversation added little difficulty to the VTS tests, and 5 (20.8%) found it very difficult to cope with the tests while talking on their cell phones.

In Table 1, the results of driving related psychomotor performance tests (Mean $\pm$ SD of score) with and without HFCC in the 1st and 2nd trials of the study are reported.

In Table 2, the associations between 5 driving related psychomotor performance tests and cell phone conversation based on mixed model analysis is presented. As demonstrated in this Table, the values of overall mean duration in the 2-hand coordination test and general intelligence as measured in the AMT test were significantly impaired during the phone conversation ($P < 0.05$).

The overall percent error duration in the 2 hand test and median deviation time in the ZBA test significantly increased during the cell phone conversation ($P < 0.01$). Also, tracking deviation (divided attention), as measured in the peripheral perception test, significantly increased during the cell phone conversation (P value = 0.053). The measures of "field of vision" in peripheral perception test and "overview", in ATAVT test, did not show any significant changes during cell phone conversation.

## 4. Discussion

In this study, we aimed at exploring how hands-free cell phone conversation (HFCC) could affect driving performance. Our findings revealed that HFCC, while driving, could cause distraction and impair psychomotor ability of the drivers with respect to visuomotor coordination, time anticipation, general intelligence, and divided attention.

Driver distraction includes visual, auditory, biomechanical, and cognitive distraction. Using HFC to converse during driving could resolve biomechanical distraction, as it happens when a driver is holding a phone, however, cognitive distraction occurs as soon as the attention of the driver deviates toward something not associated with driving (18). It turns the driver's attention away from the visual sight; thus, not all the information the driver observes is processed (7).

In line with our results, it has been reported that use of mobile phones while driving affects eye-hand coordina-

**Table 1.** The Results of Psychomotor Ability of Driving Tests According to the Order of Testing and the Hands Free Cell-Phone Conversation (Mean ± SD)

| Variables | Unit | 1st Trial | | 2nd Trial | |
|---|---|---|---|---|---|
| | | With Conversation | Without Conversation | With Conversation | Without Conversation |
| **TWO HANDS** | | | | | |
| Overall mean duration | Second | 26.05 ± 8.85 | 25.39 ± 7.95 | 23.55 ± 8.72 | 28.86 ± 11.76 |
| Overall percent error duration | - | 1.31 ± 1.04 | 0.54 ± 0.63 | 1.52 ± 1.55 | 0.90 ± 0.89 |
| **ZBA** | | | | | |
| Median deviation time | Second | 0.74 ± 0.40 | 0.60 ± 0.39 | 0.76 ± 0.28 | 0.62 ± 0.33 |
| **PP** | | | | | |
| Field of vision | Degree | 181.90 ± 9.44 | 181.83 ± 7.30 | 181.06 ± 10.63 | 180.29 ± 11.31 |
| Tracking deviation | - | 5.62 ± 0.93 | 5.51 ± 0.74 | 5.96 ± 1.05 | 5.83 ± 1.08 |
| **AMT** | | | | | |
| General intelligence | - | 0.11 ± 1.20 | 0.64 ± 1.09 | 0.38 ± 1.08 | 0.66 ± 1.07 |
| **ATAVT** | | | | | |
| Overview | - | 11.54 ± 2.38 | 12.50 ± 3.75 | 11.87 ± 2.38 | 12.37 ± 3.02 |

tion and interferes with driving (19). In addition, HFCC has a negative effect on peripheral detection, which could be aggravated as a function of the complexity of conversation (20). Those drivers, who attempt to cope with increased cognitive loads, try to concentrate on the central area of the road, which leads to delayed reaction times to a peripheral traffic event (21).

In a study by Liu et al., better performance in divided attention and precision has been reported in no conversation compared to calling situations (13).

Many studies on driver distraction refer to excessive mental workload and limited attention resources. Mental workload is the mental resources or information processing capability dedicated to a task (22). Some may consider distraction to be interruptions or failure in the procedure of attending (23). Driving is a task in which the driver has to attend 2 or more tasks simultaneously (i.e., divided attention). Since human attention resources are finite, some channels are filtered to prevent loss of driving performance. However, a total degradation in driving performance could occur in case of excessive workload. Driving requires constant response to spatial and sequential data from the environment while coordinating head, hand, and foot movements (24).

We also observed that the ability of drivers to quickly evaluate the position and direction of an object in space was affected by HFCC. Anticipation ability in driving means predicting the activities of other road users, and taking into account the natural and environmental road conditions (25). It is the most significant predictor of the tendency to negotiate hazards in traffic conditions (26).

We observed a significant decrease in general intelligence during HFCC. Fluid intelligence is a cognition ability that is related to controlled attention, especially in the exposure to interference and distraction (27). A study among 113 drivers showed that drivers with low intelligence scores were involved in more accidents at intersections and received a disproportionate number of speeding tickets (28). Drivers with lower intelligence scores may be less competent to recognize the risks and may sometimes take those risks that intelligent people would usually avoid (29).

We also detected an association between HFCC and divided attention performance. In a divided attention task, the individual is requested to display 2 or more concurrent procedures and to appropriately reply to particular stimuli (30). During a cell phone conversation, a driver is distracted cognitively and must divide his/her attention between the conversation and tasks of driving (31).

We did not detect an association among perceptual speed, field of vision, and HFCC. Perceptual speed is defined as the capacity to select details quickly in a distracting perceptual environment and distinguish them from inappropriate material (32). Maples et al., demonstrated that although cognitive tasks, such as HFCC, do not divert eyes from the road, they do decrease the field of vision (33).

Most modern vehicles are equipped with HFCC facilities, which make it easy to talk on the cell phone while driving, and making it difficult to detect this practice for authorities. This may indicate that HFCC is safe enough and it is acceptable to converse while driving if one uses hands-free equipment. However, there is increasing evidence in the literature on the risks of HFCC. Banning HFC use has

**Table 2.** Association of Psychomotor Ability Of Driving with Hands Free Cell-Phone Conversation, Controlling for the Effect of Order of testing and Gender in Mixed Model Analysis

| Test | Dependent Variable | Independent Variables | Estimates (95% CI) | P Value |
|---|---|---|---|---|
| **2HAND coordination** | Overall mean duration (second) | Intercept | 22.84 (18.36 - 27.32) | < 0.001 |
| | | Conversation (No vs. Yes) | 2.30 (0.48 - 4.12) | 0.015 |
| | | Gender (male vs. female) | 0.64 (-5.55 - 6.82) | 0.833 |
| | | Order of testing (1st vs. 2nd) | 2.87 (1.20 - 4.55) | 0.002 |
| | Overall percent error duration (Second) | Intercept | 1.23 (0.69 - 1.78) | < 0.001 |
| | | Conversation (No vs. Yes) | -0.68 (-1.02 - -0.34) | < 0.001 |
| | | Gender (male vs. female) | 0.05 (-0.41 - 0.50) | 0.834 |
| | | Order of testing (1st vs. 2nd) | 0.16 (-0.13 - 0.44) | 0.265 |
| **ZBA (Time anticipation)** | Median deviation time (second) | Intercept | 0.80 (0.64 - 095) | < 0.001 |
| | | Conversation (No vs. Yes) | -0.14 (-0.24 - -0.04) | 0.007 |
| | | Gender (male vs. female) | -0.09 (-0.30 - 0.13) | 0.414 |
| | | Order of testing (1st vs. 2nd) | 0.004 (-0.07 - 0.08) | 0.919 |
| **PP (Peripheral Perception)** | Field of vision | Intercept | 185.05 (180.49 - 189.61) | < 0.001 |
| | | Conversation (No vs. Yes) | -0.50 (-2.70 - 1.70) | 0.643 |
| | | Gender (male vs. female) | -5.23 (-11.02 - 0.56) | 0.074 |
| | | Order of testing (1st vs. 2nd) | -0.27 (-2.56 - 2.02) | 0.810 |
| | Tracking deviation | Intercept | 5.52 (5.06 - 5.99) | <0.001 |
| | | Conversation (No vs. Yes) | -0.17 (-0.35 - 0.003) | 0.053 |
| | | Gender (male vs. female) | 0.17 (-0.45 - 0.79) | 0.574 |
| | | Order of testing (1st vs. 2nd) | 0.01 (-0.20 - 0.22) | 0.907 |
| **AMT** | General intelligence | Intercept | 0.08 (-0.49 - 0.65) | 0.764 |
| | | Conversation (No vs. Yes) | 0.44 (0.15 - 0.74) | 0.005 |
| | | Gender (male vs. female) | 0.47 (-0.26 - 1.20) | 0.199 |
| | | Order of testing (1st vs. 2nd) | -0.15 (-0.42 - 0.12) | 0.258 |
| **ATAVT (Perceptual speed)** | Overview | Intercept | 11.30 (10.31 - 12.30) | < 0.001 |
| | | Conversation (No vs. Yes) | 0.76 (-0.44 - 1.95) | 0.205 |
| | | Gender (male vs. female) | 1.02 (-0.30 - 2.33) | 0.123 |
| | | Order of testing (1st vs. 2nd) | -0.22 (-1.14 - 0.69) | 0.621 |

not been successful in many countries, especially developing nations. However, regulations on HFCC seem to be necessary as a safety measure to drivers and to save the lives of other road users. These bans are only effective if most of the driving population voluntarily adhere to them, as the police simply cannot enforce this law on every occasion.

Strengths: As this study was self-controlled and conducted in a semi-experimental setting, we are confident about the reliability of the findings. The measurements were done using VTS, which is an objective and reliable instrument to assess the psychomotor performance of drivers.

Limitations: we only considered conversation via hands-free cell phone while driving and other forms of cell phone related distractions, such as making a call have not been considered. Moreover the generalization of the results may be limited due to the fact that only 20 to 39 years old university students participated in this study, and selecting different groups of drivers for future studies is recommended.

### 4.1. Conclusions

Hands-free cell phone conversation impairs driving performance and is not safe during driving. In this process, the driver's visuomotor coordination, time anticipation, divided attention, and general intelligence are most likely to be adversely affected by HFCC, however, field of vision and perceptual speed may not be remarkably altered by HFCC. Therefore, even though drivers could perceive an obstacle while conversing on a hands-free phone, it is highly likely that they react inappropriately due to impairment of visuomotor coordination, time anticipation, divided attention, and fluid intelligence.

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## Footnotes

**Authors' Contribution:** Soheil Saadat, supervision of the study, research design, performed statistical analyses, revised the study draft. Farideh Sadeghian, literature search, data collection, wrote the first draft of the manuscript, and revised. Mojgan Karbakhsh, Mahnaz Saremi, Iraj Alimohammadi, Hassan Ashayeri, and Mahsa Fayaz, contributed to the interpretation of data and revised the manuscript. All authors have approved the final manuscript.

**Conflict of Interests:** The authors declare that they have no competing interests.

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## References

1. Strayer DL, Watson JM, Drews FA. *The Psychology of Learning and Motivation*. Cognitive Distraction While Multitasking in the Automobile. In: Brian Ross , editor. **54**. Burlington: Academic Press; 2011. p. 29–58. doi: 10.1016/b978-0-12-385527-5.00002-4.
2. Oviedo-Trespalacios O, Haque MM, King M, Washington S. Effects of road infrastructure and traffic complexity in speed adaptation behaviour of distracted drivers. *Accid Anal Prev*. 2017;**101**:67–77. doi: 10.1016/j.aap.2017.01.018. [PubMed: 28189943].
3. Bergmark RW, Gliklich E, Guo R, Gliklich RE. Texting while driving: the development and validation of the distracted driving survey and risk score among young adults. *Inj Epidemiol*. 2016;**3**:7. doi: 10.1186/s40621-016-0073-8. [PubMed: 27014563].
4. Scott-Parker B, Oviedo-Trespalacios O. Young driver risky behaviour and predictors of crash risk in Australia, New Zealand and Colombia: Same but different? *Accid Anal Prev*. 2017;**99**(Pt A):30–8. doi: 10.1016/j.aap.2016.11.001. [PubMed: 27865138].
5. Strayer DL, Johnston WA. Driven to distraction: dual-Task studies of simulated driving and conversing on a cellular telephone. *Psychol Sci*. 2001;**12**(6):462–6. doi: 10.1111/1467-9280.00386. [PubMed: 11760132].
6. National Safety Council . *Understanding the distracted brain: Why driving while using hands-free cell-phone s is risky behavior. White Paper*. 2012.
7. Strayer DL, Drews FA, Johnston WA. Cell phone-induced failures of visual attention during simulated driving. *J Exp Psychol Appl*. 2003;**9**(1):23–32. doi: 10.1037/1076-898X.9.1.23. [PubMed: 12710835].
8. World Health Organization . *Global Status Report on Road Safety*. 2015.
9. Braitman KA, McCartt AT. National reported patterns of driver cell phone use in the United States. *Traffic Inj Prev*. 2010;**11**(6):543–8. doi: 10.1080/15389588.2010.504247. [PubMed: 21128181].
10. McCartt AT, Kidd DG, Teoh ER. Driver cellphone and texting bans in the United States: evidence of effectiveness. *Ann Adv Automot Med*. 2014;**58**:99–114. [PubMed: 24776230].
11. Cazzulino F, Burke RV, Muller V, Arbogast H, Upperman JS. Cell phones and young drivers: a systematic review regarding the association between psychological factors and prevention. *Traffic Inj Prev*. 2014;**15**(3):234–42. doi: 10.1080/15389588.2013.822075. [PubMed: 24372495].
12. World Health Organization . *Mobile phone use:a growing problem of driver distraction*. Geneva, Switzerland: World Health Organization; 2011.
13. Liu YC, Ou YK. Effects of age and the use of hands-free cellular phones on driving behavior and task performance. *Traffic Inj Prev*. 2011;**12**(6):550–8. doi: 10.1080/15389588.2011.607197. [PubMed: 22133330].
14. Leung S, Croft RJ, Jackson ML, Howard ME, McKenzie RJ. A comparison of the effect of mobile phone use and alcohol consumption on driving simulation performance. *Traffic Inj Prev*. 2012;**13**(6):566–74. doi: 10.1080/15389588.2012.683118. [PubMed: 23137086].
15. Karthaus M, Falkenstein M. Functional changes and driving performance in older drivers: Assessment and interventions. *Geriatrics*. 2016;**1**(2):12. doi: 10.3390/geriatrics1020012.
16. Dozza M, Flannagan CA, Sayer JR. Real-world effects of using a phone while driving on lateral and longitudinal control of vehicles. *J Safety Res*. 2015;**55**:81–7. doi: 10.1016/j.jsr.2015.09.005. [PubMed: 26683550].
17. Waugh JD, Glumm MM, Kilduff PW, Tauson RA, Smyth CC, Pillalamarri RS. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Cognitive Workload while Driving and Talking on a Cellular Phone or to a Passenger. **44**. Los Angeles, CA: SAGE Publications Sage CA; 2016. p. 6–276. doi: 10.1177/154193120004403354.
18. Ranney TA, Mazzae E, Garrott R, Goodman MJ. *Driver distraction internet forum*. NHTSA driver distraction research: Past, present, and future. 2000.
19. Brown ID, Tickner AH, Simmonds DC. Interference between concurrent tasks of driving and telephoning. *J Appl Psychol*. 1969;**53**(5):419–24. [PubMed: 5366314].
20. Amado S, Ulupınar P. The effects of conversation on attention and peripheral detection: Is talking with a passenger and talking on the cell phone different? *Transp Res Part F Traffic Psychol Behav*. 2005;**8**(6):383–95. doi: 10.1016/j.trf.2005.05.001.
21. Young KL, Salmon PM. Examining the relationship between driver distraction and driving errors: A discussion of theory, studies and methods. *Saf Sci*. 2012;**50**(2):165–74. doi: 10.1016/j.ssci.2011.07.008.
22. Birrell SA, Young MS. The impact of smart driving aids on driving performance and driver distraction. *Transp Res Part F Traffic Psychol Behav*. 2011;**14**(6):484–93. doi: 10.1016/j.trf.2011.08.004.
23. Li SY, Magrabi F, Coiera E. A systematic review of the psychological literature on interruption and its patient safety implications. *J Am Med Inform Assoc*. 2012;**19**(1):6–12. doi: 10.1136/amiajnl-2010-000024. [PubMed: 21946236].
24. Yardley L, Burgneay J, Nazareth I, Luxon L. Neuro-otological and psychiatric abnormalities in a community sample of people with dizziness: a blind, controlled investigation. *J Neurol Neurosurg Psychiatry*. 1998;**65**(5):679–84. doi: 10.1136/jnnp.65.5.679. [PubMed: 9810937].
25. Stahl P, Donmez B, Jamieson GA. Anticipatory driving competence: motivation, definition modeling. *Proceedings of the 5th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. ACM; 2013. p. 286–91.

26. Vlakveld W. *Hazard anticipation of young novice drivers*. Leidschendam, Niederlande: SWOV-Dissertation; 2011.
27. Engle RW, Tuholski SW, Laughlin JE, Conway AR. Working memory, short-term memory, and general fluid intelligence: a latent-variable approach. *J Exp Psychol Gen*. 1999;**128**(3):309–31. doi: 10.1037/0096-3445.128.3.309. [PubMed: 10513398].
28. Smith D, Kirkham R. Relationship between intelligence and driving record. *Accid Anal Prev*. 1982;**14**(6):439–42. doi: 10.1016/0001-4575(82)90057-4.
29. O'Toole BI. Intelligence and behaviour and motor vehicle accident mortality. *Accid Anal Prev*. 1990;**22**(3):211–21. doi: 10.1016/0001-4575(90)90013-b.
30. Hahn B, Wolkenberg FA, Ross TJ, Myers CS, Heishman SJ, Stein DJ, et al. Divided versus selective attention: evidence for common processing mechanisms. *Brain Res*. 2008;**1215**:137–46. doi: 10.1016/j.brainres.2008.03.058. [PubMed: 18479670].
31. Svenson O, Patten CJD. Mobile phones and driving: a review of contemporary research. *Cogn Technol Work*. 2005;**7**(3):182–97. doi: 10.1007/s10111-005-0185-3.
32. Aniței M, Schuhfried G, Chraif M. The influence of energy drinks and caffeine on time reaction and cognitive processes in young Romanian students. *Procedia Soc Behav Sci*. 2011;**30**:662–70. doi: 10.1016/j.sbspro.2011.10.128.
33. Maples WC, DeRosier W, Hoenes R, Bendure R, Moore S. The effects of cell phone use on peripheral vision. *Optometry*. 2008;**79**(1):36–42. doi: 10.1016/j.optm.2007.04.102. [PubMed: 18156094].