Transportation Research Part F: Psychology and Behaviour xxx (xxxx) xxx-xxx

Contents lists available at ScienceDirect

Transportation Research Part F: Psychology and Behaviour

journal homepage: www.elsevier.com

Higher symptoms of attention-deficit/hyperactivity disorders (ADHD) and younger age were associated with faster visual perception, but not with lower traffic violations

Seyed Hojjat Zamani Sani [a], Homayoun Sadeghi-Bazargani [b], Zahra Fathirezaie [a], Yaser Hadidi [c], Serge Brand [d, e, f]

[a] *Motor Behavior Department, University of Tabriz, Tabriz, Iran*
[b] *Road and Traffic Injury Research Centre, Tabriz University of Medical Sciences, Tabriz, Iran*
[c] *English Department, University of Tabriz, Tabriz, Iran*
[d] *University of Basel, Department of Sport, Exercise and Health, Division of Sport Science, Basel, Switzerland*
[e] *University of Basel, Adult Psychiatric Clinics (UPKE), Center for Affective, Stress and Sleep Disorders (ZASS), Basel, Switzerland*
[f] *Kermanshah University of Medical Sciences (KUMS), Department of Psychiatry, Substance Use Prevention Research Center and Sleep Disorder Research Center, Kermanshah, Iran*

ARTICLE INFO

Article history:
Received 29 April 2019
Received in revised form 6 August 2019
Accepted 15 September 2019
Available online xxx

Keywords:
Visual search
Spatial cueing
Selective attention
Driving issues
Attention-deficit/hyperactivity (ADHD)

ABSTRACT

Traffic accidents are a significant health issue in Iran, and mostly due to drivers' failures and health issues. In this view, the association between age, symptoms of attention-deficit/hyperactivity (ADHD), objective visual perception and attention (spatial cueing and visual search) and drivers' driving violations and accidents have not been investigated in Iran so far. To counter this, 183 participants (mean age: 31.65years; 147 males, 36 females) were assessed. They completed self-rating questionnaires covering sociodemographic information, driving violations, traffic accidents, and symptoms of ADHD. Further, participants' visual search and spatial cueing were objectively tested. Results showed higher symptoms of ADHD were associated with higher traffic violations and accidents, but also with a faster visual search and spatial cueing. Further, higher aging was associated with lower visual search and spatial cueing speed. Both higher ADHD scores and lower age predicted faster visual search and spatial cueing performance. The pattern of results suggests that among adults, symptoms of ADHD appeared to be both negatively associated with higher traffic violations, but also with faster visual search and spatial cueing performance. By contrast, the opposite was true as regards age. To increase traffic safety, both drivers with older age and with symptoms of ADHD appear to demand special attention.

1. Introduction

In Iran, the traffic-related prevalence of mortality is high (Abdoli, Farnia, Delavar, Dortaj, et al., 2015; Moradi & Khademi, 2009): Even if Bahadorimonfared et al. (2013) reported a peaking of traffic-related mortality rates from 51 to 65 cases per 1000 accidents until 2013, and a decreasing trend in traffic-related deaths by 2016 (Hamzeh et al., 2016), traffic accidents remain the second largest cause of mortality in Iran (Montazeri, 2004; Zangooei Dovom, Shafahi, & Zangooei Dovom, 2013), and traffic accidents are the main cause of injuries requiring surgical intervention (Mohajerani & Asghari, 2011; Motamedi et al., 2014; Zargar, Khaji, Karbakhsh, & Zarei, 2004).

There is a broad consensus that not technical malfunctions, but poor driving behavior is the main cause of traffic accidents (Abdoli et al., 2018). Here, based on the Manchester Driving Behavior Questionnaire (Reason, Manstead, Stradling, Baxter, & Campbell, 1990) and website of the Office of Applied Research of Traffic Police in the Law Enforcement Force of the Islamic

https://doi.org/10.1016/j.trf.2019.09.010
1369-8478/ © 2019.

Republic of Iran (see below), poor driving behavior is understood as aggressive violations (e.g., become angered by another driver), ordinary violations (e.g., disregarding the speed limit on a residential road/motor way, running the red line or stop sign; unauthorized overtaking; not keeping between the lanes or changing lanes without complying with the relevant regulations), errors (e.g., underestimating the speed of other drivers; driving too slow on highways or too cautious when there is no danger and no traffic), or lapses (e.g., forgetting where you have left the car in the car park). Specifically, four possible factors in poor driving behavior are discussed: psychological trait variables, psychological state variables, mental health status and sleep, and lack of attention.

Psychological trait variables to explain poor driving behavior

As extensively summarized in Abdoli et al. (2018) psychological trait variables such as higher excitement-seeking behavior (Lucidi, Mallia, Lazuras, & Violani, 2014; Mallia, Lazuras, Violani, & Lucidi, 2015), trait anxiety (Pourabdian & Azmoon, 2013), negative affectivity (Beanland, Sellbom, & Johnson, 2014), or trait aggression (Stephens & Sullman, 2015) and trait anger (Zhang & Chan, 2016) were associated with poor driving performance.

Psychological state variables to explain poor driving behavior

Further, psychological state variables such as symptoms of depression (Hilton, Staddon, Sheridan, & Whiteford, 2009; Scott-Parker, Watson, King, & Hyde, 2013), aggressive behavior (Beanland et al., 2014), and anger (Zhang & Chan, 2016) were identified as factors negatively influencing driving behavior.

Mental health status and sleep to to explain poor driving behavior

Next, health-related issues such as poor sleep and substance use disorders (Abdoli et al., 2018), poor mental health (Abdoli et al., 2018; Abdoli, Farnia, Delavar, Dortaj, et al., 2015; Abdoli, Farnia, Delavar, Esmaeili, et al., 2015) such as increased stress, symptoms of state anxiety and depression, social dysfunction, somatic complaints, but above all poor sleep were associated with poor driving.

As regards psychiatric disorders affecting driving behavior, attention-deficit/hyperactivity disorder (ADHD) deserves special attention, as symptoms of ADHD are associated with more problematic decision making (Dekkers, Popma, Agelink van Rentergem, Bexkens, & Huizenga, 2016) and lower impulse control (American Psychiatric Association, 2013). ADHD is the most common neurobiological disorder in pediatric psychiatry: Prevalence rates of ADHD are about 5.6%, and these prevalence rates did not change within the last three decades and were equally observed worldwide (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007; Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015; Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014). Further, with a prevalence rate of about 4% adult ADHD (Caci, Morin, & Tran, 2014; Caye et al., 2016; Doyle, 2004; Franke et al., 2018; Instanes, Klungsoyr, Halmoy, Fasmer, & Haavik, 2018; Moss, Nair, Vallarino, & Wang, 2007), it is evident that ADHD persists in adulthood (Agnew-Blais et al., 2016; Moffitt et al., 2015). The associations between symptoms of ADHD and driving behavior and traffic accidents have not been as much in the focus, as for instance personality traits or state-related health issues. The lack of a uniform pattern of results on the association between symptoms of ADHD and driving might be also due to methodological issues and to the fact, that not all individuals with ADHD show an increased risky driving behavior. However, overall results suggest a higher risk of driving accidents in adults with ADHD, compared to adults without ADHD (El Farouki et al., 2014; Philip et al., 2015). Further, research on this association is particularly scarce in Iran. Accordingly, the first aim of the present study was to investigate the associations between self-reported symptoms of ADHD, driving behavior and attention and visual perception performance among a sample of Iranian adult drivers.

Lack of attention to explain poor driving behavior

Somatic and psychological health issues have in common that such states negatively impact on basic psychological processes such as attention and visual perception. Indeed, the lack of attention has been recognized as one of the main causes of vehicle crashes. Various aspects of driving attention have been studied in previous research, including attention networks (Weaver, Bedard, McAuliffe, & Parkkari, 2009), attention and search conspicuity and visual context (Gershon, Ben-Asher, & Shinar, 2012), visual attention (Zhang, Chan, Ba, & Zhang, 2016), the effect of age and workload on 3D spatial attention in dual-task driving (Pierce & Andersen, 2014), and the perceptual load and driving duration on mind wandering while driving (Choi, Geden, & Feng, 2017).

In this regard, visual attention has received particular attention. Visual attention has different aspects including visual search and spatial cueing (Sternberg, 2017). Actually, visual search is a type of perceptual attention-demanding task that typically involves an active scan of the visual environment for a particular object or feature - the target - among other objects or features - the distractors (Eckstein et al., 2013; Sternberg, 2017). Further, spatial cues predicting the probable location of a target are commonly used as an operational manipulation of covert visual attention (Eckstein et al., 2013).

As regards attention and perception and driving behavior, in the meanwhile, there is mounting evidence that driving distractors may disrupt driving performance (Hosking, Young, & Regan, 2009; Salmon, Young, & Regan, 2011), and that such distractors are considered a contributing factor of road accidents (Atchley, Tran, & Salehinejad, 2017; Atwood, Guo, Fitch, & Dingus, 2018; Harbluk, Noy, Trbovich, & Eizenman, 2007; Ranney, Harbluk, & Noy, 2005). To illustrate, Dingus et al. (2016) showed that distractors caused 905 crash events over the course of three years among 3500 drivers. Likewise, attention errors have been found to be the most common factor in left-turn accidents (Larsen & Kines, 2002). By contrast, to cope with distracting situations, the risk of accident appeared to decline with increasing perception skills and with the ability to identify and select intended stimuli in a shorter reaction time, at least among novice drivers (Sagberg & Bjornskau, 2006). Likewise, increasing the alertness and expectancy of drivers to the presence of subjects can increase their search conspicuity (Gershon et al., 2012). And not surprising, when attentional load for the field of vision was low, drivers braked faster and had significantly less deviation in their steering direction (Ericson, Parr, Beck, & Wolshon, 2017). As regards data from driving simulation studies on driving behavior in adults with symptoms of ADHD, Fuermaier et al. (2017) summarized in their review that compared to drivers with no symptoms of ADHD, drivers with symptoms of ADHD showed slower and more variable reaction times, more driving errors, more collisions and crashes, more speeding, and for instance a poorer steering control. However, such data were only scarcely gathered in Iran.

Further, as mentioned above, recent studies have shown that visual attention perceptions may be influenced by symptoms of ADHD, and as regards driving performance, higher symptoms of ADHD were associated with higher traffic accidents and risky driving (Aduen, Kofler, Cox, Sarver, & Lunsford, 2015; Ankem, Klauer, Ollendick, Dingus, & Guo, 2018; Barkley & Cox, 2007; Thorslund & Lidestam, 2017). Sobanski et al. (2008) reported that adults with symptoms of ADHD showed a lower performance during a test battery of driving-related cognitive measures, and that significant improvements were observed, when participants were treated with methylphenidate. In this context, and considering both the efficacy and safety of methylphenidate, Cortese et al. (2018) showed in their systematic review and network meta-analysis the use of methylphenidate in children, adolescents and adults as preferred first-choice medications for the short-term treatment of ADHD. Likewise, Barkley and Cox (2007) mentioned in their review the increased risk of adverse outcomes among untreated individuals with ADHD and the role of medication in potentially improving driving performance. Accordingly, Barkley and Cox (2007) recommended the use of stimulant medications to treat people with ADHD who drive, as the intake of stimulants may reduce such safety risks. Next, higher symptoms of ADHD were associated with slower reaction times and poorer behavioral performances in visual-spatial attention (Ortega, Lopez, Carrasco, Anllo-Vento, & Aboitiz, 2013) and lower scores of visual attention (Turkan, Amado, Ercan, & Percinel, 2016). However, other studies could not show significant differences in visual attention and spatial performance between adults with and without symptoms of ADHD (Laasonen et al., 2012). Accordingly, it remains unclear, if and if so, to what extent symptoms of ADHD might be associated with visual attention and visual performance. In this regard, while Fuermaier et al. (2017) summarized in their review that symptoms of ADHD and poor driving were associated, Vaa (2014) showed in his meta-analysis that compared to healthy individuals, individuals with diagnosed ADHD had just a 1.36-fold risk for traffic accidents, and that the long-lasting assertion of Barkley, Guevremont, Anastopoulos, DuPaul, and Shelton (1993) that ADHD-drivers have an almost fourfold risk of accident was largely due to blurred diagnoses.

To conclude, there is extant literature showing that health-related issues were negatively associated with poor driving performance. Interestingly, Abdoli et al. (2018) were unable to find associations between health-related issues such as poor sleep and symptoms of depression and objectively assessed reaction times to visual and acoustic stimuli. Accordingly, further research is justified, and this holds particularly true for Iran. In a related vein, the associations between symptoms of ADHD and driving behavior appear to be mixed, and the moderating effect of symptoms of ADHD on the relationship between attention and visual performance and driving behavior remained unclear.

Last, there is extant evidence that with increasing age, visual processing speed decreases (Madden et al., 2002; Madden, 2007; Sternberg, 2017; Vance, Fazeli, Ball, Slater, & Ross, 2014). Accordingly, we assumed that higher age would be associated with lower attention and visual performance.

The following four hypotheses and one research question were formulated. Following others (Gershon et al., 2012; Pierce & Andersen, 2014; Weaver et al., 2009; Zhang & Chan, 2016), we expected that poor driving behavior such as reported traffic violations and accidents were associated with lower objective visual and spatial cueing performance. Second, following Vaa (2014) and Fuermaier et al. (2017), we expected a negative association between higher symptoms of ADHD and lower objective visual search and spatial cueing performance. Likewise, third and following others (El Farouki et al., 2014; Philip et al., 2015), we expected an association between higher symptoms of ADHD and poor driving behavior such as reported traffic violations and accidents. Fourth, following others (Madden et al., 2002; Madden, 2007; Sternberg, 2017; Vance et al., 2014), we assumed that higher age would be associated with lower visual search and spatial cueing processing reaction time. We took as exploratory the research question, which of the dimensions of age, symptoms of ADHD, traffic accidents and traffic violations could best predict reaction time of visual search and spatial cueing.

We hold that the present data allow a deeper understanding of the association between symptoms of ADHD, driving behavior and objective performances of visual and spatial cueing and attention. Results are relevant to improve counseling and treatment of those traffic offenders with particularly high symptoms of ADHD in Iran. Results are also relevant, as traffic accidents remain the second largest cause of mortality and the main cause of injuries requiring surgical intervention in Iran.

2. Material and methods

2.1. Procedure

Adults with a driving license were asked to participate at the present cross-sectional study on driving behavior, symptoms of ADHD, and attention (spatial cueing; see below) and perception (visual search; see below). Eligible participants were fully informed about the study aims and the confidential, anonymous, and non-commercial data handling, and the scientific use of the participants' information. Thereafter, they signed the written informed consent. Participants completed a booklet of questionnaires covering sociodemographic data, driving behavior (see below) and symptoms of ADHD (see below). Next, they underwent an objective measurement of attention and perception at the Motor Behavior Lab of the University of Tabriz (Tabriz, Iran). The procedure section lasted about 150min, including the explanation of the study, signing the written informed consent, completing the questionnaires, and undergoing perceptual testing. The perceptual testing lasted for about 40min (about 30min for the Spatial Cueing task, including instructions; and about 10min for the Visual Search task, including instructions). The ethical committee of the Tabriz University of Medical Sciences (Tabriz, Iran) approved the study, which was performed in accordance with the rules laid down in the Declaration of Helsinki and its later amendments.

2.2. Participants

Collectively, 183 adults (mean age: M=31.65, SD=9.76; 147 males, 36 females) took part in the study. Including criteria were as follows: 1. Driving license released from the Iranian government; 2. Age between 18 and 65years; 3. Willing and able to comply with the study conditions; above all, willing and able to read and answer questionnaires in Farsi/Persian; 4. Normal eye sight, or eye sight corrections with glasses or lenses to achieve normal visual acuity. 5. Being right-handed; 6. Signed written informed consent. Exclusion criteria were: 1. Current somatic and psychiatric issues, such to unfavorably impact on attention, perception, concentration and sustained alertness during the assessment lasting for about 2h. 2. Current intake of mood-, sleep-, and alertness-altering substances such as alcohol, cannabis, opioids, along with sedative medications. 3. Dropping from the study.

2.3. Tools

2.3.1. Sociodemographic information

Participants completed a questionnaire on sociodemographic information (age, gender).

2.3.2. Driving-related information

Participants reported on the preferred vehicle (car; motorcycle), the number of accidents, and the number of traffic violations.

To assess and rate driving violations, the list of 21 possible items was taken from website of the Office of Applied Research of Traffic Police in the Law Enforcement Force of the Islamic Republic of Iran. Typical items were: exceeding the speed limit, unauthorized overtaking, backing up in rear gear on freeways and highways, using a cell phone while driving, failure to comply with longitudinal or transverse distance from the front or side vehicle, overtaking from the right of the other vehicle, not keeping between the lanes or changing lanes without complying with the relevant regulations, etc. Answers are given on four-points Likert scales ranging from 1 (=not at all) to 4 (=always), with higher sum scores reflecting a higher amount of traffic violations. Possible sum scores ranged from 21 (no violations at all) to 84 (several and repeated violations).

2.3.3. Dimensions of attention-deficit/hyperactivity disorder (ADHD)

The Adult ADHD Self-Report Scale-V1.1 (Green et al., 2018; Jahangard, Haghighi, Bajoghli, Holsboer-Trachsler, & Brand, 2013; Kessler et al., 2005; Ustun et al., 2017) was used to self-assess dimensions of attention-deficit/hyperactivity disorder spectrum. Typical items are: “How often do you leave your seat in meetings or other situations in which you are expected to remain seated?”, or, “When you’re in a conversation, how often do you find yourself finishing the sentences of the people you are talking to before they can finish them themselves?”; Answers are given on rating scales with different intervals; the sum score ranges from 0 to 24 points, with higher points reflecting higher self-rated symptoms attention-deficit/hyperactivity disorder.

2.4. Attention and perception

To objectively assess attention (spatial cueing) and perception (visual search), two tests of the CogLab® software (Francis, Neath, MacKewn, & Goldthwaite, 2004) were employed. All participants performed the cognitive assessment individually in a lab office of the Motor Behavior Lab of the University of Tabriz. The lab had an average temperature of 21° and sufficient artificial light. Participants were comfortably seated in front of a 17in. monitor (1024×768 resolution; Intel® Iris Plus Graphics 640 1536MB), controlled by an Apple Mac® computer with a 2.3GHz Intel® Core i5. The screen was placed on a desk of conventional size and height. Participants were asked to sit upright, such to keep a distance of 60cm from the screen. To answer to the tasks, participants had to push buttons of the keyboard.

2.4.1. Attention: spatial cueing

In this experiment, participants’ gaze was focused on the screen. Next, they were first cued with the likely spatial location of a target, and participants had to respond as rapidly as possible when the target appeared at any location on the display. To illustrate, in a typical display, the stimuli are arranged horizontally with a fixation point in the center, which is also the location where the cue appears. The cue is either valid, correctly identifying the spatial location of the target, or invalid, incorrectly identifying the location of the target. Following the presentation of the cue, a single target stimulus is illuminated (usually about 1000 msec after the onset of the cue). Once the participant had detected the target, she/he had to respond as quickly as possible, regardless of the location of the target (Fig. 1). The outcome variable is the reaction time in msec for three conditions: valid (cue and location of the target do match), invalid (cue and location of the target do not match), neutral (no cue is presented). The ex-

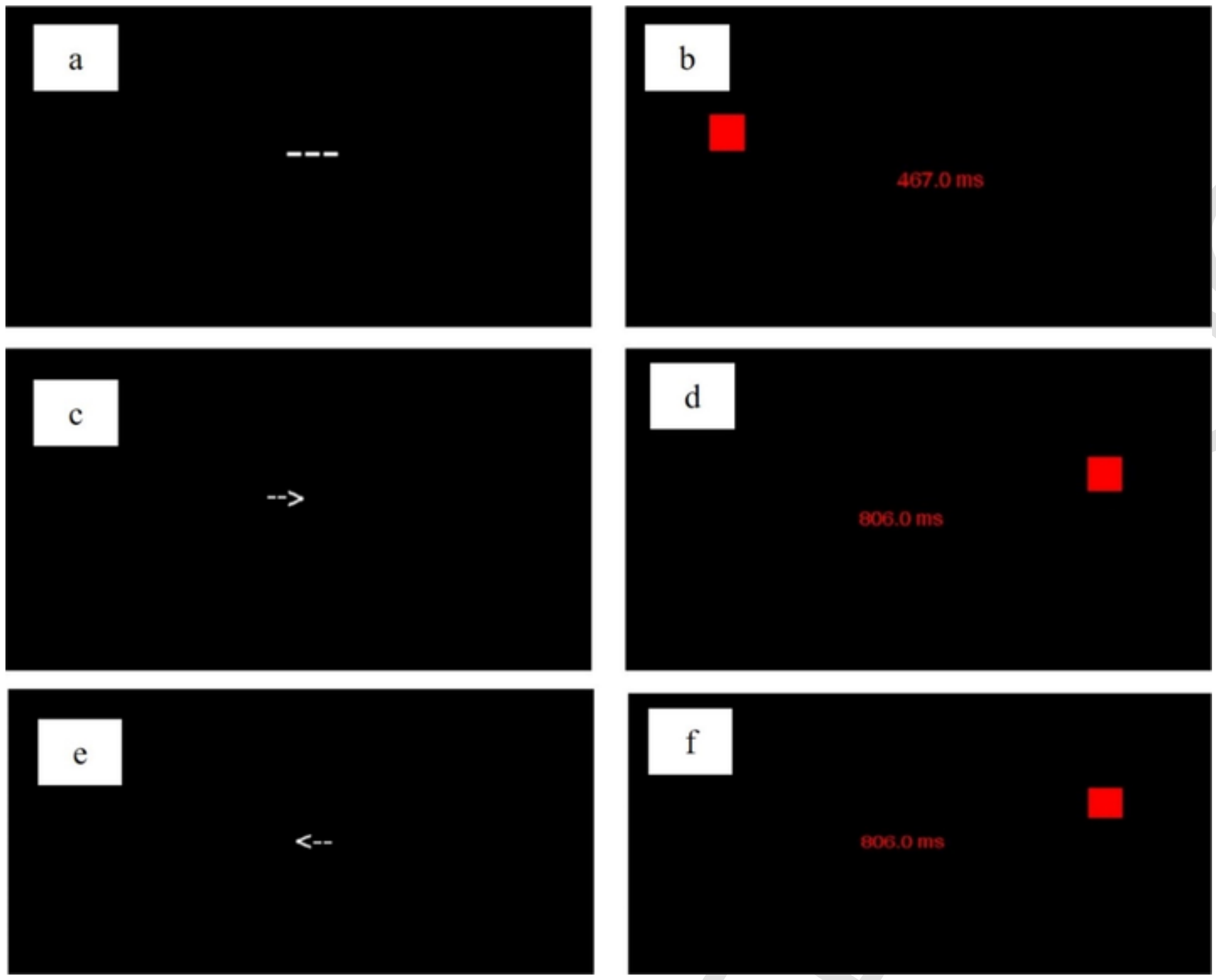

Fig. 1. Different aspects of spatial cueing on the Cog-lab software. a: natural spatial cueing, b: after natural spatial cueing red square was appearing equally likely on the left or right side of the screen; c: valid spatial cueing, d: 80% of the time, red square was appearing after valid spatial cueing on same side of the arrow; d: invalid spatial cueing, e: 80% of the time, red square was appearing after invalid spatial cueing on opposite side of the arrow. The task was to quickly respond by pressing the n key, when the participants were seeing the square, regardless of its location. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

perimental details are as follows (see also Francis et al., 2004 p. 7): After clicking on the start, a window appeared to start the experiment. To start a trial, the space bar was pressed. A fixation dot appears in the middle of the window; the participant has to stare at the fixation dot. A short time later a cue appears. If the arrow points to the right, 80% of the time the target appears to the right. If the arrow points to the left, 80% of the time the target appears to the left. If no target appears, the target is equally likely to appear on the left or right. A short time after the cue disappears, a red square appears. The participant's task is to respond as quickly as possible, when the square appears, regardless of its location. To respond, press the button. Collectively, there are 80 trials, and in every trial, the goal is to simply press the button as soon as a red square appears.

2.4.2. Perception: visual search

Participants are seated in front of the screen and asked to search a visual target and to respond as quickly as possible once they find the target, or to respond as quickly as possible, when they are certain the target is not in the screen. In this experiment, the target was a green circle. For the feature condition, the distractors were always blue squares. Accordingly, the green circle seems to pop out of the image to quickly identify the location of the target. To increase attention, the distractor items were made more complex. Some of the distractors were green squares while others were blue circles. Because some of the distractors were green, the green target circle no longer pops out and the participant must search through all the items to find the one that was both green and a circle. This type of search is a called conjunctive search because the target was a conjunction of features in the distractors (Fig. 2). The feature and conjunctive trials consist of 48 trials each. Further, the number of distractors could vary: From 4 distractors (easy condition), to 16 or to 64 distractors (demanding condition). Outcome variables was the reaction time in msec, for the following four conditions (feature condition: target present; feature condition: target absent; conjunctive condition: target present; conjunctive condition: target absent)×three distractor conditions (4, 16, 64 distractors).

The experiment was as follows (see also Francis et al., 2004; p. 19). After clicking the start button, a window appears to start the feature search experiment. After positioning the mouse in the window, the participant has to press the space bar, a fixation dot appears in the middle of the window, and the participant stares at it. Less than a second later, circles and squares of various colors appear on the screen. The participant's task is to determine if there is a green circle among the shapes. When the participant sees a green circle, she/he has to press the y button as quickly as possible. If the participant is certain there is not a green circle in the window, she/he has to press the z button again as quickly as possible.

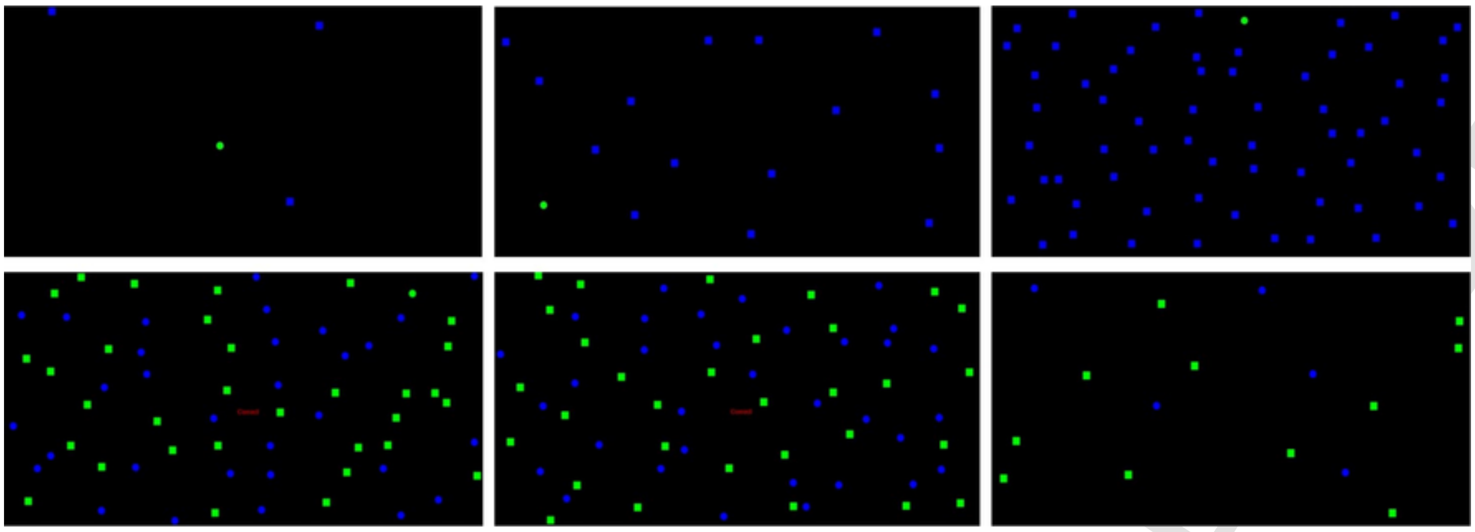

Fig. 2. Different aspects of visual search on the Cog-lab software. After clicking on the start button, a window was appearing to start the visual search experiment. A short time later (less than a second) circles and squares of various colors were appearing on the screen. The task was to determine if there is a green circle among the shapes. The presence of a green square should be answered with the/key, and the absence of that should be answered with the z key. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Every trial consists of about 48 trials. If a mistake is made, that trial is repeated in the experiment, so that a participant may actually run more that 48 trials. In every trial the goal is simply to determine if a green circle is present. If a participant is frequently incorrect (feedback is given when a participant is incorrect) the participant should try to delay the response until she/he is more certain to be correct.

2.5. Statistical analysis

With a series of Pearson's correlations, we calculated the associations between age, number of accidents, number of traffic violations, symptoms of ADHD and processing speed of spatial cueing and visual search. Next, two multiple regression analyses (stepwise backwards) were performed with the predictors age, number of accidents, number of traffic violations, and symptoms of ADHD and processing speed of spatial cueing and visual search as dependent variables.

The nominal level of significance was set at alpha<0.05. All statistical calculations were performed with SPSS® 25.0 (IBM Corporation, Armonk NY, USA) for Apple Mac®.

3. Results

3.1. Sample characteristics

A total of 183 participants (mean age=31.65years (SD=9.76; 147 males, 36 females) took part in the study. Of those, 89.7% were car drivers and 10.3% motorcycle drivers.

3.2. Traffic accidents and traffic violations and objective visual and spatial cueing performance

Table 1 reports the descriptive and correlational statistical indices. Higher traffic violations were associated with lower spatial cueing and visual search reaction time. The number of accidents and spatial cueing and visual search reaction time were generally not associated.

3.3. Symptoms of ADHD and spatial cueing and visual search reaction time

As further shown in Table 1 higher symptoms of ADHD were associated with faster spatial cueing and visual search reaction time.

3.4. Symptoms of ADHD and reported traffic violations and accidents

Higher symptoms of ADHD were associated with more accidents more traffic violations (see Table 1).

3.5. Age and spatial cueing and visual search reaction time

Higher age was associated with higher spatial cueing and visual search reaction time (see Table 1).

Table 1
Descriptive and correlative statistical indices of sociodemographic, driving-related information, symptoms of ADHD and performance of visual search/attention and spatial cueing.

	Dimensions				
Dimensions	Age	Accidents	Traffic violations	ADHD	M (SD)
Age	–	0.08	−0.39***	−0.15*	31.65 (9.76)
Accidents	–	–	0.22**	0.19*	1.12 (0.59)
Traffic violations	–	–	–	0.45***	35.72 (9.78)
ADHD	–	–	–	–	1.99 (1.14)
Spatial cueing					
Neutral	0.58***	0.13	−0.23**	−0.16*	397.37 (96.53)
Valid	0.52***	−0.06	−0.22**	−0.18*	369.29 (101.89)
Invalid	0.46***	−0.04	−0.23*	−0.17*	402.77 (142.40)
Visual search 4 distractors					
Conj absent	0.55***	−0.00	−0.20**	−0.26***	1136.01 (332.66)
Conj present	0.54***	−0.09	−0.26***	−0.15*	896.12 (268.56)
Feat absent	0.55***	0.02	−0.26***	−0.14	945.67 (397.29)
Feat present	0.47***	0.15*	−0.21**	−0.22**	738.68 (245.07)
16 distractors					
Conj absent	0.45***	−0.23	−0.21**	−0.19**	1590.83 (399.38)
Conj present	0.50***	−0.03	−0.23**	−0.18*	1133.91 (346.24)
Feat absent	0.47***	0.15**	−0.24***	−0.19*	925.57 (346.62)
Feat present	0.54***	0.09	−0.24***	−0.27***	761.87 (289.18)
64 distractors					
Conj absent	0.18**	−0.04	−0.22***	−0.15**	2492.61 (828.08)
Conj present	0.64***	0.10	0.00	−0.14	1579.20 (456.69)
Feat absent	0.33***	0.07	0.09	−0.22***	996.41 (423.86)
Feat present	0.49***	0.07	−0.24**	−0.26***	780.59 (274.62)

Notes: ADHD=attention-deficit/hyperarousal disorders; neutral=no cue is presented; valid=the cue indicates the correct direction, where the target appears; invalid=the cue indicates the opposite direction, where the target appears; conj=conjunction=distractor and target have the same color; feature=distractor and target have different colors. absent=target is not presented; present=target is presented. 4=four distractors are presented; 16=16 distractors are presented; 64=64 distractors are presented.

3.6. Age, traffic accidents, traffic violations, and symptoms of ADHD as predictors of visual search and spatial cueing

First, the three means (neutral, valid, invalid) of the spatial cueing condition were collapsed to the overall mean of spatial cueing. Likewise, the means of the 3×4 means of visual search were collapsed to the overall mean of visual search. Next, two separate multiple regression analyses were performed with the overall means as dependent variables and age, accidents, traffic violations, and symptoms of ADHD as predictors. The Durbin-Watson coefficients indicated that independence of residuals was satisfactory. Second, after stepwise exclusion, multiple regression models sufficiently explained (R and R^2) the dependent variables.

As shown in Table 2, higher symptoms of ADHD and lower age predicted faster reaction times (spatial cueing; visual search), while the number of accidents and the number of traffic violations were not entered in the equation, as they did not reach statistical significance.

Table 2
Multiple linear regressions with spatial cueing and visual search reaction times as dependent variables, and age, accidents, traffic violations and symptoms of ADHD as predictors.

Dimension	Variables	Coefficient	Standard error	Coefficient β	t	p	R	R^2	Durbin-Watson coefficient
Spatial cueing	Intercept	231.23	22.72	–	10.177	0.001	0.553	0.305	1.718
	Age	5.26	0.643	0.525	8.18	0.001			
	Symptoms of ADHD	−5.167	2.913	-0.114	2.02	0.004			
Excluded variables	Accidents, violations (all t's<1.0, all p's>0.40)								
Visual search	Intercept	750.944	69.406	–	10.171	0.001	0.559	0.312	1.756
	Age	15.816	1.964	0.514	8.05	0.001			
	Symptoms of ADHD	− 22.05	8.99	-0.158	2.478	0.0014			
Excluded variables	Accidents, violations (all t's<1.0, all p's>0.40)								

4. Discussion

The key findings of the present study were that among a sample of Iranian adult drivers, higher traffic violations were associated with lower spatial cueing and visual search reaction time, while symptoms of attention-deficit/hyperactivity disorder were both associated with higher traffic accidents and traffic violations, but also with faster reaction times for spatial cueing and visual search. Further, higher age was associated with slower reaction times for spatial cueing and visual search. Last, both higher symptoms of ADHD and younger age predicted faster reaction times for spatial cueing and visual search. The present data add to the literature in an important way, that above all symptoms of ADHD had both favorable (faster reaction time) and unfavorable (accidents and traffic violations) associations.

Four hypotheses and one research question were formulated, and each of these is considered now in turn.

With the first hypothesis we assumed that poor driving behavior such as reported traffic violations and accidents were associated with lower objective visual and spatial cueing performance, but data did not fully support this assumption: While higher traffic violations were associated with lower spatial cueing and visual search reaction time, the number of accidents and spatial cueing and visual search reaction time were generally not associated. Accordingly, the present results do not fully match those results reported in other studies (Gershon et al., 2012; Pierce & Andersen, 2014; Weaver et al., 2009; Zhang & Chan, 2016). While the quality of the data does not allow a deeper understanding of the underlying psychological mechanisms, we hypothesize the following mechanisms: It is conceivable that traffic violations might reflect higher levels of arousal and impulsivity, which remain undetected and un-punished from authorities, and which might be also mirrored in faster visual reaction times. On the flip side, such arousal and impulsivity does not equal to higher traffic accidents as a proxy of uncontrolled traffic behavior.

With the second hypothesis we expected a negative association between higher symptoms of ADHD and lower objective visual search and spatial cueing performance, but data did not confirm this: Rather, the opposite was observed, and accordingly, the pattern of results is at odds with previous research (Fuermaier et al., 2017; Vaa, 2014). Specifically, in other studies, higher symptoms of ADHD were associated with slower reaction times and poorer behavioral performances in visual-spatial attention (Ortega et al., 2013) and lower scores of visual attention (Turkan et al., 2016). One might ask as to why in the present study previous results could not be replicated. Though speculative, it is conceivable that participants with higher symptoms of ADHD considered the visual tasks as particularly exciting, with the result that their arousal increased, and that following the rule of Yerkes and Dodson (1908) their performance peaked to an optimal state. Likewise, it is conceivable that participants with higher symptoms of ADHD were more alert, compared to those with lower symptoms of ADHD. Further, variability in reaction time appears to be a stable trait among individuals with ADHD, when compared to healthy control conditions, but not, when compared to other clinical samples (Kofler et al., 2013). Last, from an evolutionary point of view, individuals willing and able to switch quickly their focus of attention as individuals with ADHD are able to do could gain some advantages, compared to individuals with slow and low switching of attention (Brüne, 2015; Stevens & Price, 2000).

With the third hypothesis we assumed an association between higher symptoms of ADHD and poor driving behavior such as reported traffic violations and accidents, and data did confirm this assumption. In this view, the present results do replicate what was observed in previous studies (El Farouki et al., 2014; Philip et al., 2015). However, we expanded upon previous results, as such an association was also observed among adult drivers in Iran.

With the fourth and last hypothesis we assumed slower reaction times with increasing age, and data did again fully confirm this. Accordingly, the present data do replicate previous studies (Madden et al., 2002; Madden, 2007).

With the exploratory research question, we investigated, if dimensions of driving behavior (accidents, traffic violations), age, and symptoms of ADHD predicted reaction times of spatial cueing and visual search. As shown in Table 2, younger age and higher symptoms of ADHD predicted faster reaction times of spatial cueing and visual search, while the number of accidents and traffic violations were excluded from the equations, as they did not reach the level of statistical significance. We hold that these results add to the current literature in an important way, as against research (Walshe, Ward McIntosh, Romer, & Winston, 2017), at least among younger adults, younger age was not associated with unfavorable visual information processing speed, understood as a proxy of driving behavior.

Despite the novelty of the data, the following limitations warn against the overgeneralization of the data. First, the sample consisted of healthy volunteers willing and able to participate to the study and to comply with the study conditions. Second, the cross-sectional design precludes causal relationships. Third, it remains unclear, if and to what extent performance of objective testing of spatial cueing and visual search is transferrable to real life driving behavior. Fourth, the tasks were such that only speed was assessed, and not accuracy. Accordingly, it is conceivable that applying other cognitive tasks such as problem-solving tasks (Tower of Hanoi; Hobbit and Orcs-tasks (Sternberg, 2017), another pattern of results would have been observed. Firth, symptoms of ADHD were self-reported, while a thorough psychiatric interview would have allowed to further confirm or reject the self-rated concept of symptoms of ADHD. Sixth, it is conceivable that latent, but unassessed psychological and physiological dimensions such as arousal, alertness, daytime sleepiness, motivation, test anxiety, or increased cortisol concentrations as a proxy of increased psychophysiological arousal might have biased two or more dimensions in the same or opposite direction. Specifically, as shown in previous studies, health-related issues such as dimensions of depression, anxiety and poor sleep might negatively impact on driving behavior (Abdoli et al., 2018; Abdoli, Farnia, Delavar, Dortaj, et al., 2015; Abdoli, Farnia, Delavar, Esmaeili, et al., 2015). In a similar vein, seventh, Cortese et al. (2018) and Barkley and Cox (Barkley & Cox, 2007) mentioned that the intake of methylphenidate (or similar stimulants) increases cognitive performance, and, among others, a more secure driving behavior. Eighth, Yordanova et al. (2011) and Burwell, Makeig, Iacono, and Malone (2019) underscored the increased rate of fluctuations of attention among individuals with ADHD. While the quality of the present data does not allow, if and to what extent also participants of the present study experienced such fluctuations both while undergoing the present testing and during their everyday driving, it is conceivable that their present performances might have been biased due to such fluctuations of attention. Last, there is sufficient evidence that poor sleep unfavorably impacts on ADHD behavior (Diaz-Roman, Mitchell, & Cortese, 2018; Keshavarzi et al., 2014); accordingly, it would have been important to assess, if and if so, to what extent sleep quality might have biased the present pattern of results.

5. Conclusion

The pattern of results suggests that among a sample of adult drivers higher symptoms of ADHD were associated both with a higher number of accidents and traffic violations, but also with faster reaction times in spatial cueing and visual search tasks. Further, older age was associated with slower reaction times. Data further suggest a complex association between fast visual information processing, younger age, higher symptoms of ADHD and higher traffic violations. The findings are clinically relevant, as they underscore the differentiated view of performance and behavior of adults with ADHD. Findings are further relevant for policy makers to decrease the risk of traffic accidents in Iran. Specifically, traffic environment and security should be improved such to reduce the odds of traffic accidents and traffic violations, but above all to reduce the cognitive load of information in the streets.

Acknowledgements

We thank all people, who participated at the present study.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

All authors declare no conflicts of interest.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2019.09.010.

References

Abdoli, N., Bahmani, D.S., Farnia, V., Alikhani, M., Golshani, S., Holsboer-Trachsler, E., Brand, S., 2018. Among substance-abusing traffic offenders, poor sleep and poor general health predict lower driving skills but not slower reaction times. Psychology Research and Behavior Management 11, 557–566. https://doi.org/10.2147/prbm.S173946.

Abdoli, N., Farnia, V., Delavar, A., Dortaj, F., Esmaeili, A., Farrokhi, N., … Brand, S., 2015. Mental health status, aggression, and poor driving distinguish traffic offenders from non-offenders but health status predicts driving behavior in both groups. Neuropsychiatric Disease and Treatment 11, 2063–2070. https://doi.org/10.2147/NDT.S89916.

Abdoli, N., Farnia, V., Delavar, A., Esmaeili, A., Dortaj, F., Farrokhi, N., … Brand, S., 2015. Poor mental health status and aggression are associated with poor driving behavior among male traffic offenders. Neuropsychiatric Disease and Treatment 11, 2071–2078. https://doi.org/10.2147/NDT.S88835.

Aduen, P.A., Kofler, M.J., Cox, D.J., Sarver, D.E., Lunsford, E., 2015. Motor vehicle driving in high incidence psychiatric disability: Comparison of drivers with ADHD, depression, and no known psychopathology. Journal of Psychiatric Research 64, 59–66. https://doi.org/10.1016/j.jpsychires.2015.03.009.

Agnew-Blais, J.C., Polanczyk, G.V., Danese, A., Wertz, J., Moffitt, T.E., Arseneault, L., 2016. Evaluation of the persistence, remission, and emergence of attention-deficit/hyperactivity disorder in young adulthood. JAMA Psychiatry 73 (7), 713–720. https://doi.org/10.1001/jamapsychiatry.2016.0465.

American Psychiatric Association, 2013. Diagnostic and statistical manual of mental disorders 5th edition: DSM 5. American Psychiatric Association, Arlington VA.

Ankem, G., Klauer, C., Ollendick, T., Dingus, T., Guo, F., 2018. 2343 - How risky are ADHD teen drivers? Analysis of ADHD teen drivers using naturalistic driving data. Journal of Transport & Health 9, S13. https://doi.org/10.1016/j.jth.2018.05.065.

Atchley, P., Tran, A.V., Salehinejad, M.A., 2017. Constructing a publically available distracted driving database and research tool. Accident Analysis and Prevention 99 (Pt A), 306–311. https://doi.org/10.1016/j.aap.2016.12.005.

Atwood, J., Guo, F., Fitch, G., Dingus, T.A., 2018. The driver-level crash risk associated with daily cellphone use and cellphone use while driving. Accident Analysis and Prevention 119, 149–154. https://doi.org/10.1016/j.aap.2018.07.007.

Bahadorimonfared, A., Soori, H., Mehrabi, Y., Delpisheh, A., Esmaili, A., Salehi, M., Bakhtiyari, M., 2013. Trends of fatal road traffic injuries in Iran (2004–2011). PLoS ONE 8 (5), e65198. https://doi.org/10.1371/journal.pone.0065198.

Barkley, R.A., Cox, D., 2007. A review of driving risks and impairments associated with attention-deficit/hyperactivity disorder and the effects of stimulant medication on driving performance. Journal of Safety Research 38 (1), 113–128. https://doi.org/10.1016/j.jsr.2006.09.004.

Barkley, R.A., Guevremont, D.C., Anastopoulos, A.D., DuPaul, G.J., Shelton, T.L., 1993. Driving-related risks and outcomes of attention deficit hyperactivity disorder in adolescents and young adults: A 3- to 5-year follow-up survey. Pediatrics 92 (2), 212–218.

Beanland, V., Sellbom, M., Johnson, A.K., 2014. Personality domains and traits that predict self-reported aberrant driving behaviours in a southeastern US university sample. Accident Analysis and Prevention 72, 184–192. https://doi.org/10.1016/j.aap.2014.06.023.

Brüne, M., 2015. Textbook of evolutionary psychiatry and psychosomatic medicine. The origins of psychopathology. Oxford University Press, Oxford UK.

Burwell, S.J., Makeig, S., Iacono, W.G., Malone, S.M., 2019. Reduced premovement positivity during the stimulus-response interval precedes errors: Using single-trial and regression ERPs to understand performance deficits in ADHD. Psychophysiology e13392. https://doi.org/10.1111/psyp.13392.

Caci, H.M., Morin, A.J., Tran, A., 2014. Prevalence and correlates of attention deficit hyperactivity disorder in adults from a French community sample. The Journal of Nervous and Mental Disease 202 (4), 324–332. https://doi.org/10.1097/nmd.0000000000000126.

Caye, A., Rocha, T.B., Anselmi, L., Murray, J., Menezes, A.M., Barros, F.C., … Rohde, L.A., 2016. Attention-deficit/hyperactivity disorder trajectories from childhood to young adulthood: Evidence from a birth cohort supporting a late-onset syndrome. JAMA Psychiatry https://doi.org/10.1001/jamapsychiatry.2016.0383.

Choi, H., Geden, M., Feng, J., 2017. More visual mind wandering occurrence during visual task performance: Modality of the concurrent task affects how the mind wanders. PLoS ONE 12 (12), e0189667https://doi.org/10.1371/journal.pone.0189667.

Cortese, S., Adamo, N., Del Giovane, C., Mohr-Jensen, C., Hayes, A.J., Carucci, S., … Cipriani, A., 2018. Comparative efficacy and tolerability of medications for attention-deficit hyperactivity disorder in children, adolescents, and adults: A systematic review and network meta-analysis. Lancet Psychiatry 5 (9), 727–738. https://doi.org/10.1016/s2215-0366(18)30269-4.

Dekkers, T.J., Popma, A., Agelink van Rentergem, J.A., Bexkens, A., Huizenga, H.M., 2016. Risky decision making in Attention-Deficit/Hyperactivity Disorder: A meta-regression analysis. Clinical Psychology Review 45, 1–16. https://doi.org/10.1016/j.cpr.2016.03.001.

Diaz-Roman, A., Mitchell, R., Cortese, S., 2018. Sleep in adults with ADHD: Systematic review and meta-analysis of subjective and objective studies. Neuroscience & Biobehavioral Reviews 89, 61–71. https://doi.org/10.1016/j.neubiorev.2018.02.014.

Dingus, T.A., Guo, F., Lee, S., Antin, J.F., Perez, M., Buchanan-King, M., Hankey, J., 2016. Driver crash risk factors and prevalence evaluation using naturalistic driving data. Proceedings of the National Academy of Sciences of the United States of America 113 (10), 2636–2641. https://doi.org/10.1073/pnas.1513271113.

Doyle, R., 2004. The history of adult attention-deficit/hyperactivity disorder. Psychiatric Clinics of North America 27 (2), 203–214. https://doi.org/10.1016/j.psc.2004.01.001.

Eckstein, M.P., Mack, S.C., Liston, D.B., Bogush, L., Menzel, R., Krauzlis, R.J., 2013. Rethinking human visual attention: Spatial cueing effects and optimality of decisions by honeybees, monkeys and humans. Vision Research 85, 5–19. https://doi.org/10.1016/j.visres.2012.12.011.

El Farouki, K., Lagarde, E., Orriols, L., Bouvard, M.P., Contrand, B., Galera, C., 2014. The increased risk of road crashes in attention deficit hyperactivity disorder (ADHD) adult drivers: Driven by distraction? Results from a responsibility case-control study. PLoS ONE 9 (12), e115002. https://doi.org/10.1371/journal.pone.0115002.

Ericson, J.M., Parr, S.A., Beck, M.R., Wolshon, B., 2017. Compensating for failed attention while driving. Transportation Research Part F: Traffic Psychology and Behaviour 45, 65–74. https://doi.org/10.1016/j.trf.2016.11.015.

Francis, G., Neath, I., MacKewn, A., Goldthwaite, D., 2004. CogLab. Wadsworth/Thomson Learning, Belmont CA.

Franke, B., Michelini, G., Asherson, P., Banaschewski, T., Bilbow, A., Buitelaar, J.K., … Reif, A., 2018. Live fast, die young? A review on the developmental trajectories of ADHD across the lifespan. European Neuropsychopharmacology 28 (10), 1059–1088. https://doi.org/10.1016/j.euroneuro.2018.08.001.

Fuermaier, A.B., Tucha, L., Evans, B.L., Koerts, J., de Waard, D., Brookhuis, K., … Tucha, O., 2017. Driving and attention deficit hyperactivity disorder. Journal of Neural Transmission (Vienna) 124 (Suppl 1), 55–67. https://doi.org/10.1007/s00702-015-1465-6.

Gershon, P., Ben-Asher, N., Shinar, D., 2012. Attention and search conspicuity of motorcycles as a function of their visual context. Accident Analysis and Prevention 44 (1), 97–103. https://doi.org/10.1016/j.aap.2010.12.015.

Green, J.G., DeYoung, G., Wogan, M.E., Wolf, E.J., Lane, K.L., Adler, L.A., 2018. Evidence for the reliability and preliminary validity of the Adult ADHD Self-Report Scale v1.1 (ASRS v1.1) Screener in an adolescent community sample. International Journal of Methods in Psychiatric Research e1751. https://doi.org/10.1002/mpr.1751.

Hamzeh, B., Najafi, F., Karamimatin, B., Ahmadijouybari, T., Salari, A., Moradinazar, M., 2016. Epidemiology of traffic crash mortality in west of Iran in a 9 year period. Chinese Journal of Traumatology 19 (2), 70–74.

Harbluk, J.L., Noy, Y.I., Trbovich, P.L., Eizenman, M., 2007. An on-road assessment of cognitive distraction: Impacts on drivers' visual behavior and braking performance. Accident Analysis and Prevention 39 (2), 372–379. https://doi.org/10.1016/j.aap.2006.08.013.

Hilton, M.F., Staddon, Z., Sheridan, J., Whiteford, H.A., 2009. The impact of mental health symptoms on heavy goods vehicle drivers' performance. Accident Analysis and Prevention 41 (3), 453–461. https://doi.org/10.1016/j.aap.2009.01.012.

Hosking, S.G., Young, K.L., Regan, M.A., 2009. The effects of text messaging on young drivers. Human Factors 51 (4), 582–592. https://doi.org/10.1177/0018720809341575.

Instanes, J.T., Klungsoyr, K., Halmoy, A., Fasmer, O.B., Haavik, J., 2018. Adult ADHD and comorbid somatic disease: A systematic literature review. Journal of Attention Disorders 22 (3), 203–228. https://doi.org/10.1177/1087054716669589.

Jahangard, L., Haghighi, M., Bajoghli, H., Holsboer-Trachsler, E., Brand, S., 2013. Among a sample of Iranian students, adult attention deficit hyperactivity disorder is related to childhood ADHD, but not to age, gender, socioeconomic status, or birth order–an exploratory study. International Journal of Psychiatry in Clinical Practice 17 (4), 273–278. https://doi.org/10.3109/13651501.2013.800555.

Keshavarzi, Z., Bajoghli, H., Mohamadi, M.R., Salmanian, M., Kirov, R., Gerber, M., … Brand, S., 2014. In a randomized case-control trial with 10-years olds suffering from attention deficit/hyperactivity disorder (ADHD) sleep and psychological functioning improved during a 12-week sleep-training program. The World Journal of Biological Psychiatry 15 (8), 609–619. https://doi.org/10.3109/15622975.2014.922698.

Kessler, R.C., Adler, L., Ames, M., Demler, O., Faraone, S., Hiripi, E., … Walters, E.E., 2005. The World Health Organization Adult ADHD Self-Report Scale (ASRS): A short screening scale for use in the general population. Psychological Medicine 35 (2), 245–256.

Kofler, M.J., Rapport, M.D., Sarver, D.E., Raiker, J.S., Orban, S.A., Friedman, L.M., Kolomeyer, E.G., 2013. Reaction time variability in ADHD: A meta-analytic review of 319 studies. Clinical Psychology Review 33 (6), 795–811. https://doi.org/10.1016/j.cpr.2013.06.001.

Laasonen, M., Salomaa, J., Cousineau, D., Leppamaki, S., Tani, P., Hokkanen, L., Dye, M., 2012. Project DyAdd: Visual attention in adult dyslexia and ADHD. Brain and Cognition 80 (3), 311–327. https://doi.org/10.1016/j.bandc.2012.08.002.

Larsen, L., Kines, P., 2002. Multidisciplinary in-depth investigations of head-on and left-turn road collisions. Accident Analysis and Prevention 34 (3), 367–380.

Lucidi, F., Mallia, L., Lazuras, L., Violani, C., 2014. Personality and attitudes as predictors of risky driving among older drivers. Accident Analysis and Prevention 72, 318–324. https://doi.org/10.1016/j.aap.2014.07.022.

Madden, D.J., 2007. Aging and visual attention. Current Directions in Psychological Science 16 (2), 70–74. https://doi.org/10.1111/j.1467-8721.2007.00478.x.

Madden, D.J., Turkington, T.G., Provenzale, J.M., Denny, L.L., Langley, L.K., Hawk, T.C., Coleman, R.E., 2002. Aging and attentional guidance during visual search: Functional neuroanatomy by positron emission tomography. Psychology and Aging 17 (1), 24–43.

Mallia, L., Lazuras, L., Violani, C., Lucidi, F., 2015. Crash risk and aberrant driving behaviors among bus drivers: The role of personality and attitudes towards traffic safety. Accident Analysis and Prevention 79, 145–151. https://doi.org/10.1016/j.aap.2015.03.034.

Moffitt, T.E., Houts, R., Asherson, P., Belsky, D.W., Corcoran, D.L., Hammerle, M., … Caspi, A., 2015. Is adult ADHD a childhood-onset neurodevelopmental disorder? Evidence from a four-decade longitudinal cohort study. American Journal of Psychiatry 172 (10), 967–977. https://doi.org/10.1176/appi.ajp.2015.14101266.

Mohajerani, S.H., Asghari, S., 2011. Pattern of mid-facial fractures in Tehran, Iran. Dental Traumatology 27 (2), 131–134. https://doi.org/10.1111/j.1600-9657.2011.00979.x.

Montazeri, A., 2004. Road-traffic-related mortality in Iran: A descriptive study. Public Health 118 (2), 110–113. https://doi.org/10.1016/s0033-3506(03)00173-2.

Moradi, S., Khademi, A., 2009. Survey of victims of car accidents year 1387. Journal of Forensic Medicine (Persian) 15, 21–28.

Moss, S.B., Nair, R., Vallarino, A., Wang, S., 2007. Attention deficit/hyperactivity disorder in adults. Primary Care: Clinics in Office Practice 34 (3), 445–473 https://linkinghub.elsevier.com/retrieve/pii/S0095454307000395https://doi.org/10.1016/j.pop.2007.05.005.

Motamedi, M.H., Dadgar, E., Ebrahimi, A., Shirani, G., Haghighat, A., Jamalpour, M.R., 2014. Pattern of maxillofacial fractures: A 5-year analysis of 8,818 patients. The Journal of Trauma and Acute Care Surgery 77 (4), 630–634. https://doi.org/10.1097/ta.0000000000000369.

Ortega, R., Lopez, V., Carrasco, X., Anllo-Vento, L., Aboitiz, F., 2013. Exogenous orienting of visual-spatial attention in ADHD children. Brain Research 1493, 68–79. https://doi.org/10.1016/j.brainres.2012.11.036.

Philip, P., Micoulaud-Franchi, J.A., Lagarde, E., Taillard, J., Canel, A., Sagaspe, P., Bioulac, S., 2015. Attention deficit hyperactivity disorder symptoms, sleepiness and accidental risk in 36140 regularly registered highway drivers. PLoS ONE 10 (9), e0138004. https://doi.org/10.1371/journal.pone.0138004.

Pierce, R.S., Andersen, G.J., 2014. The effects of age and workload on 3D spatial attention in dual-task driving. Accident Analysis and Prevention 67, 96–104. https://doi.org/10.1016/j.aap.2014.01.026.

Polanczyk, C.A., de Lima, M.S., Horta, B.L., Biederman, J., Rohde, L.A., 2007. The worldwide prevalence of ADHD: A systematic review and metaregression analysis. American Journal of Psychiatry 164 (6), 942–948. https://doi.org/10.1176/ajp.2007.164.6.942.

Polanczyk, G.V., Salum, G.A., Sugaya, L.S., Caye, A., Rohde, L.A., 2015. Annual research review: A meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. Journal of Child Psychology and Psychiatry 56 (3), 345–365. https://doi.org/10.1111/jcpp.12381.

Polanczyk, C.A., Willcutt, E.G., Salum, G.A., Kieling, C., Rohde, L.A., 2014. ADHD prevalence estimates across three decades: An updated systematic review and meta-regression analysis. International Journal of Epidemiology 43 (2), 434–442. https://doi.org/10.1093/ije/dyt261.

Pourabdian, S., Azmoon, H., 2013. The relationship between trait anxiety and driving behavior with regard to self-reported iranian accident involving drivers. International Journal of Preventive Medicine 4 (10), 1115–1121.

Ranney, T.A., Harbluk, J.L., Noy, Y.I., 2005. Effects of voice technology on test track driving performance: Implications for driver distraction. Human Factors 47 (2), 439–454. https://doi.org/10.1518/0018720054679515.

Reason, J., Manstead, A., Stradling, S., Baxter, J., Campbell, K., 1990. Errors and violations on the roads: A real distinction?. Ergonomics 33 (10–11), 1315–1332. https://doi.org/10.1080/00140139008925335.

Sagberg, F., Bjornskau, T., 2006. Hazard perception and driving experience among novice drivers. Accident Analysis and Prevention 38 (2), 407–414. https://doi.org/10.1016/j.aap.2005.10.014.

Salmon, P.M., Young, K.L., Regan, M.A., 2011. Distraction 'on the buses': A novel framework of ergonomics methods for identifying sources and effects of bus driver distraction. Applied Ergonomics 42 (4), 602–610. https://doi.org/10.1016/j.apergo.2010.07.007.

Scott-Parker, B., Watson, B., King, M.J., Hyde, M.K., 2013. A further exploration of sensation seeking propensity, reward sensitivity, depression, anxiety, and the risky behaviour of young novice drivers in a structural equation model. Accident Analysis and Prevention 50, 465–471. https://doi.org/10.1016/j.aap.2012.05.027.

Sobanski, E., Sabljic, D., Alm, B., Skopp, G., Kettler, N., Mattern, R., Strohbeck-Kuhner, P., 2008. Driving-related risks and impact of methylphenidate treatment on driving in adults with attention-deficit/hyperactivity disorder (ADHD). Journal of Neural Transmission (Vienna) 115 (2), 347–356. https://doi.org/10.1007/s00702-007-0834-1.

Stephens, A.N., Sullman, M.J., 2015. Trait predictors of aggression and crash-related behaviors across drivers from the United Kingdom and the Irish Republic. Risk Analysis 35 (9), 1730–1745. https://doi.org/10.1111/risa.12379.

Sternberg, R.J., 2017. Cognitive psychology, seventh ed. CENGAGE Learning, Boston MA, USA.

Stevens, A., Price, J., 2000. Evolutionary Psychiatry. A new beginning. Routledge. Taylor & Francis Group, London UK, New York NY, USA.

Thorslund, B., Lidestam, B., 2017. 2037 – Effects of ADHD on driving behaviour and attention. Journal of Transport & Health 5, S77. https://doi.org/10.1016/j.jth.2017.05.227.

Turkan, B.N., Amado, S., Ercan, E.S., Percinel, I., 2016. Comparison of change detection performance and visual search patterns among children with/without ADHD: Evidence from eye movements. Research in Developmental Disabilities 49–50, 205–215. https://doi.org/10.1016/j.ridd.2015.12.002.

Ustun, B., Adler, L.A., Rudin, C., Faraone, S.V., Spencer, T.J., Berglund, P., … Kessler, R.C., 2017. The World Health Organization adult attention-deficit/hyperactivity disorder self-report screening scale for DSM-5. JAMA Psychiatry 74 (5), 520–526. https://doi.org/10.1001/jamapsychiatry.2017.0298.

Vaa, T., 2014. ADHD and relative risk of accidents in road traffic: A meta-analysis. Accident Analysis and Prevention 62, 415–425. https://doi.org/10.1016/j.aap.2013.10.003.

Vance, D.E., Fazeli, P.L., Ball, D.A., Slater, L.Z., Ross, L.A., 2014. Cognitive functioning and driving simulator performance in middle-aged and older adults with HIV. Journal of the Association of Nurses in AIDS Care 25 (2), e11–e26. https://doi.org/10.1016/j.jana.2013.12.001.

Walshe, E.A., Ward McIntosh, C., Romer, D., Winston, F.K., 2017. Executive function capacities, negative driving behavior and crashes in young drivers. International Journal of Environmental Research and Public Health 14 (11)https://doi.org/10.3390/ijerph14111314.

Weaver, B., Bedard, M., McAuliffe, J., Parkkari, M., 2009. Using the Attention Network Test to predict driving test scores. Accident Analysis and Prevention 41 (1), 76–83. https://doi.org/10.1016/j.aap.2008.09.006.

Yerkes, R.M., Dodson, J.D., 1908. The relation of strength of stimulus to rapidity of habit-formation. Journal of Comparative Neurology and Psychology 18 (5), 459–482. https://doi.org/10.1002/cne.920180503.

Yordanova, J., Albrecht, B., Uebel, H., Kirov, R., Banaschewski, T., Rothenberger, A., Kolev, V., 2011. Independent oscillatory patterns determine performance fluctuations in children with attention deficit/hyperactivity disorder. Brain 134 (Pt 6), 1740–1750. https://doi.org/10.1093/brain/awr107.

Zangooei Dovom, H., Shafahi, Y., Zangooei Dovom, M., 2013. Fatal accident distribution by age, gender and head injury, and death probability at accident scene in Mashhad, Iran, 2006–2009. International Journal of Injury Control and Safety Promotion 20 (2), 121–133. https://doi.org/10.1080/17457300.2012.692694.

Zargar, M., Khaji, A., Karbakhsh, M., Zarei, M.R., 2004. Epidemiology study of facial injuries during a 13 month of trauma registry in Tehran. Indian Journal of Medical Sciences 58 (3), 109–114.

Zhang, T., Chan, A.H., 2016. The association between driving anger and driving outcomes: A meta-analysis of evidence from the past twenty years. Accident Analysis and Prevention 90, 50–62. https://doi.org/10.1016/j.aap.2016.02.009.

Zhang, T., Chan, A.H.S., Ba, Y., Zhang, W., 2016. Situational driving anger, driving performance and allocation of visual attention. Transportation Research Part F: Traffic Psychology and Behaviour 42, 376–388. https://doi.org/10.1016/j.trf.2015.05.008.