SELF-REPORTED ATTENTIONAL FAILURES DURING DRIVING RELATES TO ON-ROAD CRASHES AND SIMULATED DRIVING PERFORMANCE OF OLDER DRIVERS

HeeSun Choi[1], Daniel Grühn[1], & Jing Feng[1]*

[1]Department of Psychology, North Carolina State University

*Corresponding Author:

Dr. Jing Feng

Department of Psychology, North Carolina State University

Campus Box 7650, Raleigh, NC 27695-7650, United States

jing_feng@ncsu.edu

Tel: (919)-515-3411

Fax: (919)-515-1716

E-mail: jing_feng@ncsu.edu

ABSTRACT

Older drivers experience increasing risks of a motor vehicle crash as they age. The increased crash risks among older drivers are associated with age-related declines in cognitive functioning, particularly in attentional abilities. Failures in attentional processing can severely impair driving performance. We developed a questionnaire, the Attentional Failures during Driving Questionnaire (AFDQ), to measure the frequency of attentional failures in driving. Initial evidence suggested that the AFDQ was a reliable and valid measure of attentional abilities in driving, and was able to reflect age differences on these abilities. In this paper, we describe our efforts to further develop the AFDQ to a short version based on a factor analysis of the items. We examined the effectiveness of the AFDQ in a survey study and then a simulated driving study with older drivers. Results from our survey study suggested that the AFDQ score was well associated with scores from other established self-report measures of cognitive and driving abilities. The frequency of attentional failures as measured by the AFDQ was found to predict older drivers' self-reported numbers of vehicle warnings, citations and crashes in the past five years. Findings from the simulated driving study showed that the AFDQ score was related to a set of driving performance measures, including the number of collisions with pedestrians and the number of off-road collisions and centerline crossings. The findings from both studies suggest that the AFDQ is an effective measure in capturing attentional declines that could affect driving risks among older drivers.

INTRODUCTION

Older drivers make up a large and fast growing segement of the driver population in the United States. In 2012, there were more than 35 million licensed drivers age 65 or older, representing approximately 17% of all drivers (*1*). By 2030, the number of older drivers (age 65+) will raise to 57 million (*2*), representing 25% of all drivers (*3*). This increase in both the absolute number and also in the percentage of older drivers pose challenges to driving safety, as older drivers are increasingly prone to fatal vehicle crashes as they age. Older drivers experience higher risks of fatal crashes per mile driven than middle-aged drivers (*4*). The increased fatal crash rates among older drivers have been associated with both physical fragility (*5*) and age-related declines in cognitive functioning (*6*). Among cognitive factors, deteriorations in attention have been identified as one of the leading causes of increased vehicle crash risks among older drivers (*7-9*).

Attention is the ability to concentrate on some information in the environment while ignoring others. Attention selects what is important and relevant to the current task for further processing and disregards unimportant information. Driving is a dynamic and demanding task which requires attention to pick out important information from the driving environment. Such involvement of attention in driving can be observed in a variety of forms. For example, identifying hazardous objects from the visually-cluttered driving environment (e.g, a cyclist entering the driver's way) is critical for safe driving (selective attention; *10*). Early detection of driving hazards in the visual periphery enhances effective visual scanning by the driver (spatial coverage of attention, *11*). In addition, a driver has to remain alert during driving. Being drowsy leads to reduced ability to detect and avoid driving hazards (sustained attention; *12*). And, when a driver needs to complete a secondary task such as switching on the light before entering a tunnel, the driver has to divide attention to both the light switching task and the maneuvering task (divided attention, *13*). In the dynamic task of driving, all of these attentional facets are necessary in maintaining driving safety.

With increasing age, an indvidual's attentional capabilities decline (see *14* for a review). has Age-related declines have been found in various forms of attention that are critical for driving safety, including (a) selective attention (*15*), (b) spatial coverage of attention (*16, 17*), (c) sustained attention (*18*), and (d) divided attention (*13*, *19*). For example, the impacts of age-related attentional declines on driving performance has been studied using the Useful Field Of View (UFOV) test. This test is designed to assess attentional ability across an extended visual field. Studies have found that UFOV score is associated with driving safety and crash risks (7, *8*) among older drivers. In particular, one study showed that older drivers who had 40% or more reduction of a maximum 30° visual field size were about twice more likely to be involved in a crash during the follow-up 3 years (*20*). These findings suggest that impairments in attentional ability are associated with increased crash risks in older drivers.

Given the important role that attentional deterioration plays in increased crash risks, detection of attentional impairments can inform older drivers about potential declines in their ability to drive safely, and sebsquently help older drivers to develop effective coping strategies such as modifying driving behaviors or seeking for cognitive intervention. An easy-to-use tool for monitoring attentional abilities in driving, such as a brief questionnaire, can be used to assess the attentional fitness-to-drive of older drivers in a rehabilitation setting or even at home. Such an instrument would provide older drivers with insights into changes in their driving abilities due to attentional declines, helping older drivers to determine when efforts are needed to improve their driving safety. In addition, a brief questionnaire to assess attentional abilities in driving can be used in research to understand how the ability to deal with various driving situations changes due to attentional deterioration.

We developed Attentional Failure during Driving Questionnaire (AFDQ, *21*) that assesses driving risks due to attention-related errors in driving. This questionnaire is primarily designed for drivers who may experience increased driving risks due to attentional declines with advancing age. The questionnaire may be used by older drivers as a self-monitoring tool providing insights into potentially increasing crash risks and initial indicator about whether further driving assessment about one's driving ability such as on-road tests is necessary. The initial version of the AFDQ consisted of a total of 33 items representing a broad spectrum of driving-related attentional facets, including selecting important information from a visual clutter (selective attention; example item: "After a quick glance over your shoulder to check the blind spot, you find that you did not get enough information and have to check again"), detecting critical events in the visual periphery (spatial coverage of attention; example item: "You are so focused on the road ahead that you fail to promptly notice a car in the next lane attempting to merge into your lane"), being attentive over time (sustained attention; example item: "You forget to turn off your turn signal after a lane change has been completed"), and dividing attention among multiple tasks (divided attention; example item: "While checking an in-vehicle display (e.g. GPS screen), you fail to promptly notice that you are getting too close to the vehicle in front of you"). The AFDQ measures the frequency of attentional failure situations experienced during driving in the past six months. Each item is rated on a six-point Likert scale from *never* (0), *hardly ever* (1), *occasionally* (2), *quite often* (3), *frequently* (4), to *nearly all the time* (5). Completing the 33-item AFDQ takes about 10 minutes.

In a first survey study (n = 374, age range: 18 – 85 years; *21*), we examined the reliability and validity of our initial version of the AFDQ with 33 items. We found that older drivers, who were 75 years or older, reported a higher frequency of attentional failures than three younger age groups (25-44 years, 45-64 years, or 65-74 years). This finding is consistent with age differences in attentional abilities using computerized laboratory tasks (*18, 19*). The 33-item AFDQ was also well associated with scores from established self-report measures of attention in daily activities other than driving and with scores from self-report measures of general driving ability. These results suggest that the newly-developed AFDQ is an effective measure of attentional ability in driving, and can potentially become a useful fitness-to-drive assessment for older drivers. In our preliminary analyses, the 33 items in the AFDQ showed a high internal consistency (Cronbach's $\alpha = .97$, *21*). The high internal consistency suggests that some items in the questionnaire closely resemble each other, thus the initial version of the questionnaire may be revised by reducing overlapping items. In addition, the effectiveness of the questionnaire can be further examined in relation to more objective measures of older drivers' abilities in driving, such as simulated driving performance, on-road driving performance, and the numbers of on-road citations and crashes.

In this paper, we describe our efforts to revise the 33-item Attentional Failure during Driving Questionnaire (AFDQ) to a brief version, and further investigations on the construct, reliability and validity of this questionnaire. According to our exploratory and confirmatory factor analyses, we reduced the AFDQ to a short version of 19 items. We examined the reliability and validity of the 19-item AFDQ in two experiments with older drivers. In a survey study, we investigated how well the score from the 19-item AFDQ predicted self-reported numbers of driving warnings, citations, and crashes in the past five years. In a following simulated driving study, we examined the association between the AFDQ score and simulated driving performance. Here we present the revised AFDQ, its factor construct, the association with other self-report attentional and driving measures, its relation with self-report on-road citations and vehicle crashes, and the relation between the AFDQ score and simulated driving performance of older drivers.

STUDY 1: SURVEY STUDY

This survey study examined the factor construct of the AFDQ using exploratory and confirmatory factor analyses based on responses from older drivers. A briefer version of the AFDQ was formed according to the results from the factor analyses. We analyzed the associations between the AFDQ score (from the brief version) and other self-reported measures of attention and driving. This study also used structural equation modeling with latent variables to investigate the relation between the AFDQ score and self-reported numbers of warnings, citations and crashes among older drivers.

Participants

A total of 185 older drivers (age range: 65-94 years) participated in the survey study. Five responses were excluded from analyses due to being incomplete or inappropriate (e.g., response rating was the same across all items). The participants were recruited from online and local communities. All participants had valid driver's license, and most participants self-reported to drive at least"a few days a month". A summary of participants demographics and self-reported numbers of vehicle warnings, citations, and crashes in the past five years is presented in Table 1.

TABLE 1 Descriptive Statistics of Older Drivers in Study 1 (Survey Study) and Study 2 (Simulated Driving Study)

	Study 1 (Survey Study)			Study 2 (Simulated Driving Study)		
	Male	Female	Total	Male	Female	Total
# of participants	108	72	180	14	8	22
Age	76.2 (5.27)[1]	74.5 (6.53)	75.54 (5.86)	78.2 (4.12)	80.1 (4.32)	78.9(4.20)
Yrs Licensed	55.8 (10.68)	53.9 (10.44)	55.1 (10.59)	61.9 (5.20)	62.3 (2.96)	62.0 (4.44)
# of warnings[2]	0.49 (1.13)	0.36 (.95)	0.44 (1.06)	0.07 (0.27)	0.13 (0.35)	0.09 (0.29)
# of citations[2]	0.33 (0.91)	0.26 (0.82)	0.29 (0.86)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
# of crashes[2]	0.22 (0.78)	0.31 (0.87)	0.25 (0.81)	0.21 (0.43)	0.0 (0.0)	0.14 (0.35)

[1] Mean (Standard deviation)
[2] Number of warnings, citations, crashes in the past five years
[3] Samples of study 2 were signicantly older than of study 1, p <.05. Years of licensed and numbers of warnings, citations, and crashes did not differ between two participant samples.

Measures

In addition to demographic details, participants reported their driving experience (e.g., when did they obtain the driver's license) and driving history (e.g., numbers of vehicle warnings, citations and crashes in the past five years). Participants also completed a set of established self-report measures of daily attentional and cognitive abilities, and measures of driving ability. The self-report measures of attention and cognition are the *Cognitive Failure Questionnaire (CFQ; 22*), the *Attention-Related Cognitive Errors Scale (ARCES; 23*), and the *Adult Attention Deficit and*

Hyperactivity Disorder (ADHD) Self-Report Scale (ASRS; 24). The self-report measures of driving abilities include the *Manchester Driver Behavior Questionnaire (DBQ, 25*), the *Susceptibility to Driver Distraction Questionnaire (SDDQ, 26*), and the *Adelaide Driving Self-Efficacy Scale (ADSES, 27*). These external scales measuring attentional and driving abilities were the same as those used in our earlier study (*21*). We used standard scoring methods defined by each scale. A detailed description of the scales and the scoring methods were provided in (*21*).

Results

Factor analyses support a briefer version of the AFDQ

To examine the structure of the 33-item AFDQ, we conducted an exploratory factor analysis (EFA). Findings from the EFA were suggestive of a one-factor structure. The scree plot was indicative of one large factor extracting 62.9% of the variance. A potential second, third, or fourth factor extracted 4.1%, 0.9%, or 0.8% of the variance, respectively. In addition, no consistent loading patterns could be observed for a two-, three-, or four-factor solution. Other factors than the first were primarily driven by cross-loadings of items that already load on the first factor. Based on these findings, we assumed the 1-factor solution to be the best representation of the data. In an effort to create a briefer version of the AFDQ, we removed items with communalities of less than .60 from the one-factor solution. This procedure removed items that did not share substantial variance with the first extracted factor. Given this criterion, 19 items remained (13 items were dropped). The wording of these items as well as the loadings from the EFA are presented in Table 2. All loadings were high.

To support the findings from the exploratory factor analysis, we also performed a confirmatory factor analysis (CFA) in Mplus (*28*). We used this procedure to test whether the one-factor solution yield an appropriate structural representation of the attention-in-driving measures derived from the EFA (see *28* for a recommendation of this procedure). We modeled one latent factor with the 19 items as observed indicators. The one-factor model showed adequate fit to the data, $\chi^2(152) = 387.5$, $p < .01$, CFI = .90, TLI = .90, RMSEA = .10 [.08; .12]. Factor loadings of each questionnaire item from the CFA are reported in Table 2. All loadings were high and generally supported the findings from the EFA.

AFDQ score is consistent with established measures of attention and driving

The overall score of the 19-item version of the AFDQ was $M = 1.04$, SD = .94 ($M = 1.67$, SD = .68 if excluding responses of "never"). Based on the 19-item version, correlations were computed between the AFDQ and relevant self-report measures on attentional and cognitive abilities in everyday living (CFQ, ARCES, ASRS) as well as self-reported driving abilities (DBQ, SDDQ, ADSES). The correlation coefficients are listed in Table 3. The results indicated significant positive correlations of the AFDQ score with everyday cognitive failures (AFDQ-CFQ, $r = .56$, $p < .001$), attention-related errors during daily activities (AFDQ-ARCES, $r = .55$, $p < .001$), and symptoms of attention deficit (AFDQ-ASRS, $r = .54$, $p < .001$). In general, self-reported attentional failures during driving was significantly associated with engagement in driver distraction (AFDQ–SDDQ Eng, $r = .41$, $p < .001$), suggesting that among older drivers, engagement in distraction were likely due to a weaker ability to ignore distracting information (AFDQ–SDDQ InV, $r = .30$, $p < .001$), rather than a greater intention from the driver to engage in distraction (AFDQ–SDDQ Vol, $r = -.02$, $p = .78$). In addition, the results indicated that self-reported attentional failures during driving were positively correlated with a variety of unsafe driving behaviors, including driving errors (AFDQ-DBQ Err, $r = .86$, $p < .001$), lapses (AFDQ-DBQ Lap, $r = .80$, $p < .001$), and violations (AFDQ-DBQ Vio, $r = .77$, $p < .001$). The results also showed a negative correlation between the AFDQ score and drivers' self-efficacy in driving (AFDQ–ADSES, $r = -.42$, $p < .001$), implying that older drivers who experienced a higher level of attentional failures are less confident about their driving abilities.

TABLE 2 The 19-item Attentional Failures during Driving Questionnaire (AFDQ) and Corresponding Factor Loadings based on an Exploratory (EFA) and Confirmatory Factor analysis (CFA)

Items[1]	EFA	CFA
1. When entering a roundabout or intersection, you fail to notice vehicles that are not straight ahead.	.825	.843
2. When preparing to turn onto a main road, you pay so much attention to the traffic on the main road that you nearly run into the car in front of you.	.880	.870
3. On a busy street, you fail to notice a 'Stop' or 'Yield' sign, almost hitting a car that has the right of way.	.861	.873
4. When checking the rear-view or side mirrors, you fail to promptly notice that the car in front of you brakes.	.858	.851
5. You fail to promptly notice vehicles and pedestrians in your way when driving along a busy downtown street.	.851	.842
6. You continue to follow the traffic, without noticing that the light at an intersection has turned red.	.869	.861
7. You are looking for a specific point at the road, and you fail to promptly notice that the car in front of you brakes.	.838	.826
8. When you are talking on a phone, you fail to promptly notice that there is a vehicle or pedestrian in your way.	.845	.879
9. You start to cross the intersection once the oncoming vehicles are moving, but then realize that your light has not turned green yet.	.870	.850
10. Before switching lanes, you are so focused on the traffic in the lane that you wish to join and you fail to notice promptly that the vehicle in front of you brakes.	.868	.877
11. You fail to notice an animal coming onto the road and you nearly hit the animal.	.818	.834
12. You are so focused on the road ahead that you fail to promptly notice a car in the next lane attempting to merge into your lane.	.847	.842
13. During a right turn, you fail to notice a cyclist or pedestrian who is entering the crosswalk from the right side, and you almost hit the person.	.831	.813
14. You do not notice a vehicle driving by your side, until it passes you.	.807	.763
15. You fail to notice road signs when they are not straight ahead.	.821	.787
16. Another driver honks at you making you realize that the traffic light has turned green.	.808	.781
17. You attention is captured by visual characters of surrounding vehicles (e.g., vehicle design, license plate, decorative object) that you fail to notice road information such as traffic signs and pedestrians.	.793	.772
18. You fail to check the rear-view or side mirrors before pulling out or changing lanes.	.831	.796
19. Roadside advertisements capture your attention while driving that you fail to promptly notice that the vehicle in front of you is slowing down.	.862	.864

[1]Participants rated each item on a 6-point Likert scale, "Never", "Hardly Ever", "Occasionally", "Quite Often", "Frequently", "Nearly All the time"

TABLE 3 Correlations between the AFDQ score and scores from other self-report measures on daily attentional and cognitive capabilities, driving abilities and self-efficacy in driving

					SDDQ			DBQ			
Measures	**AFDQ**	**CFQ**	**ARCES**	**ASRS**	**Eng**	**Vol**	**InV**	**Err**	**Lap**	**Vio**	**ADSES**
Mean (SD)	1.04 (.94)	2.25 (.67)	2.34 (.74)	1.19 (1.47)	2.16 (.63)	2.79 (.64)	2.80 (.86)	1.01 (.90)	1.23 (.89)	.97 (.89)	7.85 (2.24)
AFDQ[1]	-										
CFQ[2]	.56*	-									
ARCES[3]	.55*	.86*	-								
ASRS[4]	.54*	.71*	.67*	-							
SDDQ[5]											
Eng[6]	.41*	.50*	.43*	.37*	-						
Vol[7]	-.02	.31*	.19*	.16*	.64*	-					
InV[8]	.30*	.41*	.34*	.31*	.19*	.09	-				
DBQ[9]											
Err[10]	.86*	.62*	.59*	.59*	.44*	.04	.36*	-			
Lap[11]	.80*	.70*	.68*	.60*	.47*	.08	.38*	.90*	-		
Vio[12]	.77*	.55*	.50*	.54*	.50*	.14	.29*	.87*	.82*	-	
ADSES[13]	-.42*	-.44*	-.44*	-.39*	-.04	.17*	-.33*	-.38*	-.38*	-.17*	-

[1]AFDQ: Attentional Failure during Driving Questionnaire (higher scores – more failures; range: 0-5)
[2]CFQ: Cognitive Failures Questionnaire (higher scores – more failures; range 1-5)
[3]ARCES: Attention-Related Cognitive Errors Scale (higher scores – more errors; range 1-5)
[4]ASRS: Adult ADHD Self-Report Scale (higher score – greater ADHD symptoms; range: 0-6)
[5]SDDQ: Susceptibility to Driver Distraction Questionnaire (higher score-greater susceptibility to driving distraction; [6]Eng: Engagement, range 1-5; [7]Vol: Voluntary, range 1-5; [8]InV: Involuntary, range 1-5)
[9]DBQ: Manchester Driver Behavior Questionnaire (higher scores – more unsafe driving behaviors; **[10]**Err:Errors, range 0-5; **[11]**Lap: lapses, range 0-5; **[12]**Vio: Violations, range 0-5)
[13]ADSES: Adelaide Driving Self-Efficacy Scale (higher scores– greater confidence, range: 0-10)

AFDQ score predicts self-reported number of driving warnings, citations, and crashes

Given the nature of the frequency assessment of the AFDQ items, it is rare that people experienced all attention failure situations in the past six months. Indeed, only half of the times, the AFDQ items were endorsed to have occurred (ranging from 39% to 73%). Thus, the data is highly skewed in that most people responded with *never* (0) to many items. In order to deal with this skewed distribution pattern, we decided to disentangle the occurrence of an attentional failure from the frequency of the attentional failure with a two-part model. The model generates a different factor for the occurrence of an attentional failure and the frequency of the occurrence. For example, one older driver may experience only a few particular attentional failures but very frequently, while another older driver may have many attentional failures but less frequently. These two older drivers may have differential risk of being involved in driving-related crashes and the two-part model tries to distinguish that by modeling two latent factors (*30*). The first latent factor represents the occurrence (yes/no) of an attentional failure; the second latent factor represents the frequency of the occurrence (from "hardly ever" to "nearly all the time"). This model is derived using Mplus (*28*). Each of the 19 items of the AFDQ was recoded into two new variables representing the occurrence of an attentional failure (0 = no, 1 = yes) and the frequency of the occurrence (1 = *hardly ever* to 5 = *nearly all the time*). If an attentional failure did not occur for a person, the corresponding frequency variable was given a missing value.

The 19 new occurrence items and the 19 new frequency items were used as indicators for a latent occurrence factor and a latent frequency factor, respectively. The two latent factors were then modeled to be predictors of self-reported driving warnings, citations and crashes in the past five years. In addition, age was included in the model as a predictor for both latent variables as well as the three outcome variables.

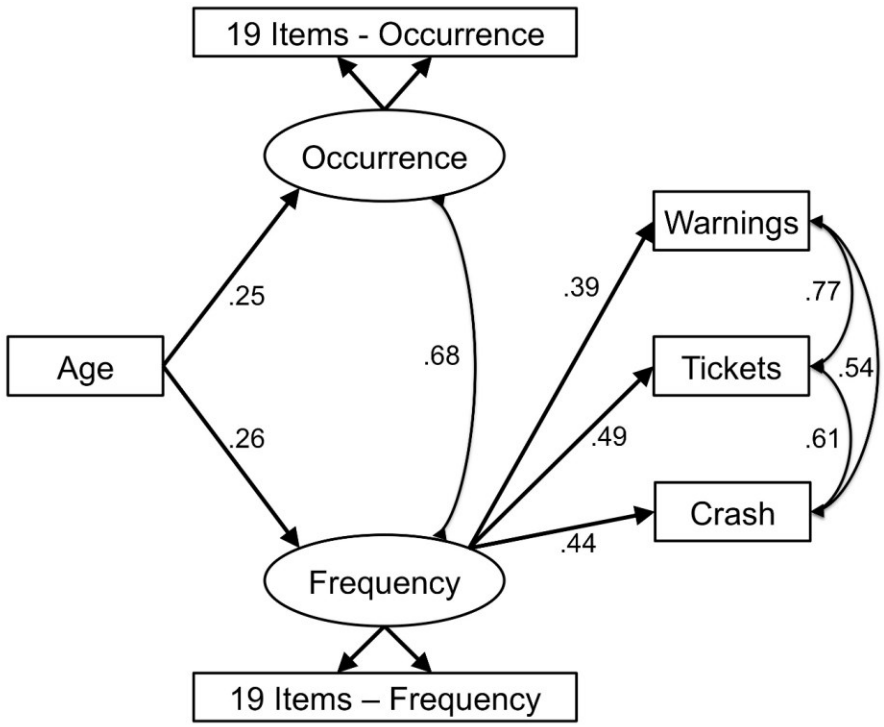

FIGURE 1 Structural model predicting driving warnings, citations and crashes from latent variables of the occurrence and frequency of attentional failures during driving.

Despite the complexity of the two-part model, the model showed adequate fit to the data, $\chi^2(808) = 974.5$, $p < .01$, CFI = .91, TLI = .91, RMSEA = .05 [.04; .06]. The model is depicted in Figure 1. The loadings for the occurrence factor – ranging between .65 and .82 – and the frequency factor – ranging between .66 and .85 – were reasonably high. To simplify the figure, the individual indicators for the two latent factors are just represented by a large box and non-significant paths were omitted. In particular, age and the occurrence of attentional failures were not predictive of the three driving-related outcomes. Age was, however, predictive of both, the occurrence and the frequency of attentional failures, which indicates that among the old drivers (age range: 65-94 years), the old-old drivers (age range: 75 and up years) reported more occurrences and a higher frequency of these occurrences than the young-old drivers (age range: 65-74 years). Only the frequency of attention failures was a significant and substantial predictor of driving-related outcomes. Older drivers (age range: 65-94 years) who reported more frequent attentional failures, reported getting more warnings, citations, and were involved in more vehicle crashes than old drivers who reported lower frequencies on AFDQ.

This model suggested the frequency of the occurrence of the attentional failures (i.e., given a driver experience particular attentional failures in driving, how frequent are these attentional failures) but not the occurrence directly predicted vehicle warnings, citations and crashes. Older drivers in general experience more frequent attentional failures during driving compare to middle-aged drivers (*21*). Among older drivers, individual differences may be more clearly reflected on the frequency rather than the occurrence as many situations of attentional failures may have occurred to older drivers. Interestingly, age was not directly predictive of warnings, citations and crashes. This observation suggests that the effect of age on driving performance is mediated by the degree of attentional declines. For an individual older driver, being older in the old age does not necessarily mean a higher risk of vehicle crashes. Large individual variations exist in the degree of attentional and cognitive declines. This degree of decline, rather than age per se, predicts crash risks.

STUDY 2: SIMULATED DRIVING STUDY

The survey study showed clear links between the AFDQ score and driving performance measures, such as the numbers of warnings, citations, and crashes. To corroborate the findings based on the self-report data, we conducted a lab study with simulated driving. We predicted that the AFDQ would also predict older drivers' performance on simulated driving.

Participants

22 older drivers (age range: 75-85 years, mean age: 79 years, 14 men, eight women) participated in this study. They were recruited from the local communities. Five out of the 22 participants reported that they experienced simulator sickness during the practice drive, thus did not complete the study. Our analyses included data from 17 participants (12 men, five women, mean age: 79 years). Every participants had a valid government issued driver's license, and reported a minimum of 12 years of education, normal or corrected-to-normal vision and no self-reported history of neurological or vision disorders. All older drivers in the study reported driving almost every day.

Simulated driving

A PC-based, desktop version of STISIM Drive 3 simulator was used for the simulated driving task. Driving scenes were presented on a high-resolution 42" monitor at a distance of approximately 70 cm (visual angel: $67.2^o \times 40.0^o$). Driving was controlled by a Logitech Driving Force GT driving wheel and pedals, and participants' driving performance was sampled at a rate of 60 Hz.

Participants had a practice simulated driving before the experiment testing. The practice was a simple route drive similar to what was used in the experiment, which consists of driving straight, turning left and turning right at various intersection conditions. The practice drive took about 5 minutes, and verbal instructions and demonstrations were provided to a participant by the experimenter during the practice when needed. In the experiment session, participants were instructed to drive through a route of 2.9 km, which included both urban and rural driving environment. The experiment drive took about 10 minutes, and it consisted of three stop-sign and six traffic signal intersections. Auditory instructions were presented to participants to guide the traveling directions. For each of the three travelling directions (i.e., left, straight and right), there were one stop-sign intersection and two traffic signal intersections. A set of driving hazards were implemented along the drive: 1) a pedestrian walking into the path of the vehicle (occurred two times); 2) a deer running into the road (appeared one time); 3) a parked vehicle suddenly merging into the path of the vehicle (occurred two times). To minimize the expectation of these hazards, participants did not practice their reactions to these hazards. The simulated drive consisted of a large number of dynamic (e.g., vehicles, pedestrians) and static objects (e.g., buildings, trees) to reflect everyday driving environment. Participants were instructed to drive just as how he/she regularly drives.

Procedure

Participants completed both the newly developed Attentional Failures during Driving Questionnaire (AFDQ) and a session of driving in a simulator. For simulated driving, participants completed a practice drive and then the experiment drive. The experiement was a part of a larger study which included other surveys and various computer-based cognitive tests, and the entire experiment took about 1.5 to 2 hours.

Results

AFDQ score is associated with simulated driving performance

Participants' simulated driving performance was assessed using two compound measures: (1) object detection and avoidance, (2) lane maintainance. The compound measure of object detection and avoidance was computed as the sum of number of number of collisions with a vehicle, number of collisions with a pedestrian or an animal, and number of stop signs missed, number of off-road collisions. These incidents were grouped together as they are related to poorer ability to identify important objects and react approporiately. The compound meassure of lane maintainance was computed as the sume of number of off-road collisions and number of centerline crossings. Both incidents are associated with degraded skills in maneuvering. We used compound measures rather than the individual incident measures as we could only have a few repetitions of each driving condition (to make the short drive reasonably natural).

Participants were divided into high attentional failure drivers (n = 8) and low attentional failure drivers (n = 9) on the basis of a median-split for the 19-item AFDQ score. As expected, given the median split, the low attentional failure group (M = 0.6, SD = 0.3) reported on average less attentional failures during driving than the high attentional failure group (M = 1.4, SD = 0.9), $F(1,15) = 5.97$, $p < .05$, $\eta^2 = .29$.The simulated driving performances of the two groups were compared.

We then compared the high and low attentional failure groups on the measures of simulated driving performance. Generally consistent with expectations, the low attentional failure groups outperformed the high attentional failure group in simulated driving. In particular, the high attentional failure group had many more off-road collisions and centerline crossings (M = 3.4, SD = 2.4) than the low attentional failure group (M = 1.4, SD = 1.2), $F(1, 15) = 4.55$, $p =.05$, $\eta^2 = .23$. The high attentional failure group also had about 0.8 more crashes and misses of stop signs (M = 1.8, SD = 1.5) than the low attentional failure group (M = 1.0, SD = 0.9), though the group difference did not reach significance, $F(1,15) = 1.66$, $p = .22$, $\eta^2 = .10$. Inspecting each of the measures individually, there was a significant group difference on the number of collisions with pedestrians, $F(1,15) = 5.91$, $p < .05$. $\eta^2 = .28$. The high attentional failure group (M = 0.8, SD = 0.7) had significant more collisions with pedestrians than the low attentional failure group (M = 0.1; SD = 0.3). In addition, the high attentional failure group took more than two minutes longer to complete the drive (M = 641 seconds, SD = 270 seconds) than the low attentional failure group (M = 495 seconds, SD = 85 seconds) approaching significance, $F(1,15) = 2.38$, $p = .14$, $\eta^2 = .14$.

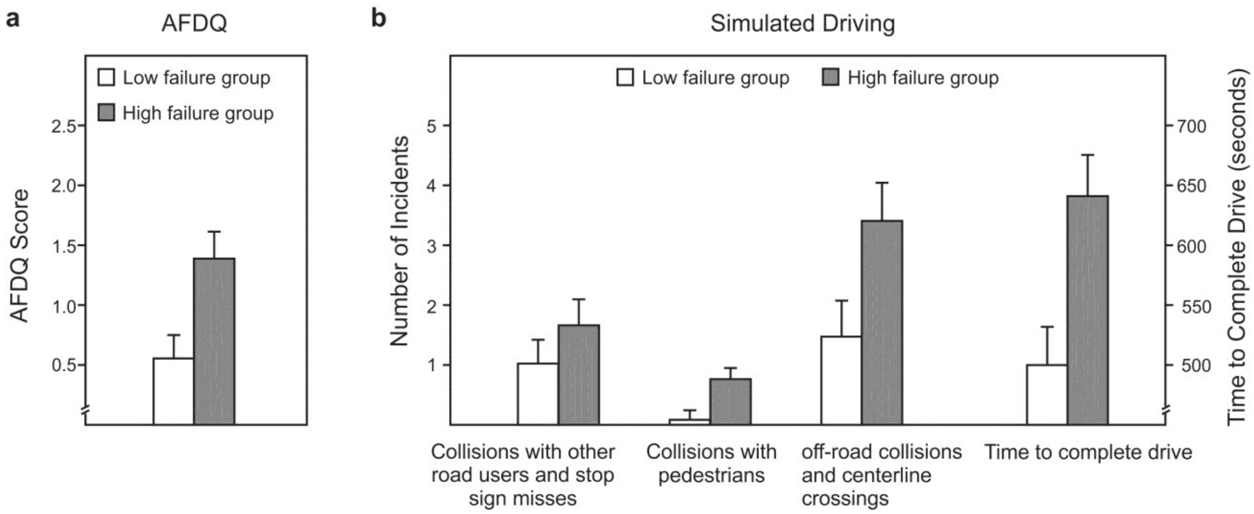

FIGURE 2 Simulated driving performance on lane keeping, object detection and avoidance by the inferior and superior groups of older drivers from a median split based on AFDQ score.

DISCUSSION

The major goal of this study was to further develop the Attentional Failures during Driving Questionnaire (AFDQ) and to examine the factor construct and validity of the questionnaire. Based on our results from the exploratory and confirmatory factor analyses, we formed a 19-item version of the AFDQ. Using responses of older drivers in a survey study, scores on this briefer version of the AFDQ was compared against other established questionnaires measuring attentional and cognitive capabilities in everyday life, and driving abilities. We also developed a structural model using the occurrence and frequency indecies extracted from the AFDQ responses as latent variables describing the relation among age, the AFDQ scores and self-reported numbers of driving warnings, citations and crashes in the past five years among older drivers. In a simulated driving study with older drivers, we investigated the relation between the AFDQ score and simulated driving performance. Below is a summary of our findings:

- Older drivers with more attentional failures during driving reported more failures in everyday attention and cognition, and more symptoms of attention deficit;
- Older drivers who reported more attentional failures during driving also experienced more driving errors, lapses and violations, and were more likely to engage in driver distraction;
- Older drivers with more attentional failures had low self-efficacy in driving;

- Among older drivers, age was predictive of both the occurrence and the frequency of attentional failures during driving (i.e., older drivers of greater age reported more occurrences and a higher frequency of attentional failures during driving);
- Neither age nor the occurrence of attentional failures directly predicted driving warnings, citations and crashes. The frequency of the occurrence of attentional failures during driving was a strong predictor of self-reported numbers of warnings, citations and crashes in the past five years;
- Older drivers who reported more attentional failures during driving had more off-road and centerline crossing accidents in simulated driving;
- Older drivers who reported more attentional failures had more collisions with pedestrians during simulated driving.

In sum, the results indicated that the 19-item Attentional Failures during Driving Questionnaire (AFDQ) is an effective measure that predicts older drivers' driving risks. This questionnaire is a tool that is relatively easy to use for detecting age-related attentional declines in older drivers. Such a tool that allows older drivers to assess their attentional abilities in driving, can help older drivers become aware of the changes in their attentional abilities and the impacts on driving. A brief questionnaire which requires only about 10 minutes to complete would be much easier to use as an intital assessment tool, compared to assessments using computers, driving simulators, or on-road driving. In addition, the questionnaire that examines attentional abilities in driving can be beneficial for researchers who investigate the impacts of the attentional deterioration on driving performance.

In the current study, we investigated how well the AFDQ score predicts older drivers' driving abilities using self-reported retrospective crash history and performance in a simulated driving. Future studies using longitudinal methods can examine the relation between the AFDQ score and prospective citation and crash measures. The current study also used a relatively brief drive with a brief practice session. In future studies, driving performance can be measured with extended and more comprehensive simulated driving task or even on-road driving task. For example, with more repetitions of each driving conditions during the simulated drive, more stable data would be able to provide a clearer picture of the association between the AFDQ score and simulated driving performance. A longer practice may also be helpful to older drivers as they are likely less famililar with a simulated driving environment as compared with other age groups. Furthermore, Our investigation was primarily based on the self-reported questionnaire measure. It is possible that older drivers who experience cognitive impairments such as memory loss with advancing age might not be able to accurately report their cognitive failures. Further validation would need to examine the sensitivity and specificity of the AFDQ when used by older drivers. Finally, differential impacts of the occurrence and frequency of attentional failures during driving on self-reported crash history were found in our study. Given that a lot of the attentional failures described in the AFDQ are relatively common, it is likely that everyone experienced them every once in a while. Thus, the occurrence might be less informative than how often the attention failure occurred. This observation warrants further investigations on the effects of occurrence and frequency of attentional failures on driving abilities among different age groups and the underlying attentional mechnisms of safe driving.

ACKNOWLEDGEMENT

This research was supported by the North Carolina State University College of Humanities and Social Sciences (CHASS) Scholarship and Research Award to Jing Feng, and the Human Factors and Ergonomics Society (HFES) Aging Technical Group scholarship to HeeSun Choi. We would like to thank Anika N. Khan for assisting in data collection in Experiment 2.

REFERENCES

1. Federal Highway Administration (FHWA). *Higway Statistics 2012*. Washington, DC, 2012.
2. Federal Highway Administration (FHWA). *Highway Statistics 2003*. Washington, DC, 2004.
3. Highway Loss Data Institute. Estimating the effect of projected changes in the driving population on collision claim frequency. *Bulletin*, Vol. 29, No. 8, 2012, pp. 1-9.
4. Tefft, B. C. *Motor vehicle crashes, injuries, and deaths in relation to driver age: United States, 1995-2010*. Washington, DC: AAA Foundation for Traffic Safety, 2012.
5. Li, G., E. R. Braver, and L. H. Chen. Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. *Accident Analysis & Prevention*, Vol. 35, No. 2, 2003, pp. 227-235.
6. Anstey, K. J., J. Wood, S. Lord, and J. G. Walker. Cognitive, sensory and physical factors enabling driving safety in older adults. *Clinical psychology review*, Vol. 25, No. 1, 2005, pp. 45-65.
7. Ball, K.K., C. Owsley, M. E. Sloane, D. L. Roenker, and J. R. Bruni. Visual attention problems as a predictor of vehicle crashes among older drivers. *Investigative Ophthalmology & Visual Science,* Vol. 34, 1993, pp. 3110-3123.
8. Clay, O. J., V. G. Wadley, J. D. Edwards, D. L. Roth, D. L. Roenker, and K. K. Ball. Cumulative meta-analysis of the relationship between useful field of view and driving performance in older adults: current and future implications. *Optometry and Vision Science,* Vol. 82, 2005, pp. 724–731.
9. Friedman, C., G. McGwin, K. K. Ball, and C. Owsley. Association between higher order visual processing abilities and a history of motor vehicle collision involvement by drivers ages 70 and over. *Investigative ophthalmology & visual science*, Vol. 54, No. 1, 2013, pp. 778-782.
10. Trick, L. M., J. T. Enns, J. Mills, and J. Vavrik. Paying attention behind the wheel: a framework for studying the role of selective attention in driving. *Theoretical issues in Ergonomic Science,* Vol. *5*, No. 5, 2004, pp. 385-424.
11. Coeckelbergh, T.M., W. H. Brouwer, F. W. Cornelissen, P. van Wolffelaar, and A. C. Kooijman. The effect of visual field defects on driving performance: A driving simulator study. *Archives of Ophthalmology,* Vol. 120, No. 11, 2002, pp. 1509-1516.
12. Åkerstedt, T., B. Peters, A. Anund, and G. Kecklund. Impaired alertness and performance driving home from the night shift: a driving simulator study. *Journal of Sleep Research,* Vol. 14, 2005, pp. 17–20.

13. Pond, R. W. H. M., W. H. Brouwer, and P. C. V. Wolffelaar. Age differences in divided attention in a simulated driving task. *The Journal of Gerontology*, Vol. 43, No. 6, 1988, pp. 151-156.
14. Kramer, A. F., and D. J. Madden. Attention. In F. I. M. Craik & T. A. Salthouse (Eds)., *The Handbook of Aging and Cognition* (3rd ed., pp.189–249). New York, USA: Psychology Press, 2008.
15. Quigley, C., S. K. Andersen, L. Schulze, M. Grunwald, and M. M. Müller. Feature-selective attention: evidence for a decline in old age. *Neuroscience letters*, Vol. 474, No. 1, 2010, pp. 5-8.
16. Ball, K.K., B. L. Beard, D. L. Roenker, R. L. Miller, and D. S. Griggs. Age and visual search: Expanding the useful field of view. *Journal of the Optical Society of America,* Vol. 5, No. 12, 1988, pp. 2210-2219.
17. Feng, J., F. I. M. Craik, B. Levine, S. Moreno, and G. Naglie. Differential age-related changes in attention across an extended visual field, in revision.
18. McAvinue, L. P., T. Habekost, K. A. Johnson, S. Kyllingsbæk, S. Vangkilde, C. Bundesen, and I. H. Robertson. Sustained attention, attentional selectivity, and attentional capacity across the lifespan. *Attention, Perception, & Psychophysics*, Vol. 74, No. 8, 2012, pp. 1570-1582.
19. Fraser, S., and L. Bherer. Age-related decline in divided-attention: from theoretical lab research to practical real-life situations. *Wiley Interdisciplinary Reviews: Cognitive Science*, Vol. 4, No. 6, pp. 623-640.
20. Owsley, C., Ball, K., McGwin Jr, G., Sloane, M. E., Roenker, D. L., White, M. F., & Overley, E. T. (1998). Visual processing impairment and risk of motor vehicle crash among older adults. *Jama*, *279*(14), 1083-1088.
21. Choi, H., and J. Feng. Attentional failures during driving. To appear in *the Proceedings of the 2014 International Annual Meeting of the Human Factors and Ergonomics Society*, Chicago, IL, USA, in press.
22. Broadbent, D. E., P. F. Cooper, P. FitzGerald, and K. R. Parkes. The cognitive failures questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology,* Vol. 21, 1982, pp. 1-16.
23. Carriere, J. S., J. A. Cheyne, and D. Smilek. Everyday attention lapses and memory failures: The affective consequences of mindlessness. *Consciousness and cognition*, Vol. 17, No. 3, 2008, pp. 835-847.
24. Kessler, R. C., L. Adler, M. Ames, O. Demler, S. Faraone, E. V. A. Hiripi, M. J. Howes, R. Jin, K. Secnik, T. Spencer, T. B. Ustun, and E. E. Walters. The World Health Organization Adult ADHD Self-Report Scale (ASRS): a short screening scale for use in the general population. *Psychological medicine*, Vol. 35, 2004, pp. 245-256.
25. Reimer, B., L. A. D'Ambrosio, J. Gilbert, J. F. Coughlin, J. Biederman, C. Surman, R. Fried, and M. Aleardi. Behavior differences in drivers with attention deficit hyperactivity disorder: The driving behavior questionnaire. *Accident Analysis and Prevention,* Vol. 37, 2005, pp. 996-1004.

26. Feng, J., S. Marulanda, and B. Donmez. Susceptibility to driver distraction questionnaire (SDDQ): Development and relation to relevant self-reported measures. *Transportation Research Record: Journal of the Transportation Research Board*, in press.
27. George, S., M. Clark, and M. Crotty. Development of the Adelaide Driving Self-Efficacy Scale. *Clinical Rehabilitation,* Vol. 21, 2007, pp. 56-61.
28. Muthén, L. K., and B. O. Muthén. *Mplus User's Guide* (5th ed.). Los Angeles, CA: Muthén & Muthén, 2007.
29. Hopwood, C. J., and M. B. Donnellan. How should the internal structure of personality inventories be evaluated? *Personality and Social Psychology Review*, Vol. 14, 2010, pp. 332-346.
30. Schneider, S. and A. A. Stone. Distinguishing between frequency and intensity of health-related symptoms from diary assessments. *Journal of Psychosomatic Research*, in press.