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Development of a novel driving behavior adaptations questionnaire

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ABSTRACT

Background: Driving a car requires adapting one's behavior to current task demands taking into account one's capacities. With increasing age, driving-relevant cognitive performance may decrease, creating a need for risk-reducing behavioral adaptations. Three different kinds of behavioral adaptations are known: selection, optimization, and compensation. These can occur on the tactical and the strategic level. Risk-reducing behavioral adaptations should be considered when evaluating older drivers' traffic-related risks.

Methods: A questionnaire to assess driving-related behavioral adaptations in older drivers was created. The questionnaire was administered to 61 years older (age 65–87 years; mean age = 70.2 years; SD = 5.5 years; 30 female, 31 male) and 31 younger participants (age 22–55 years; mean age = 30.5 years; SD = 6.3 years; 16 female and 15 male) to explore age and gender differences in behavioral adaptations.

Results: Two factors were extracted from the questionnaire, a risk-increasing factor and a risk-reducing factor. Group comparisons revealed significantly more risk-reducing behaviors in older participants ($t(84.5) = 2.21$, $p = 0.013$) and females ($t(90) = 2.52$, $p = 0.014$) compared, respectively, to younger participants and males. No differences for the risk-increasing factor were found ($p > 0.05$).

Conclusions: The questionnaire seems to be a useful tool to assess driving-related behavioral adaptations aimed at decreasing the risk while driving. The possibility to assess driving-related behavioral adaptations in a systematic way enables a more resource-oriented approach in the evaluation of fitness to drive in older drivers.

Key words: behavioral adaptations, selection, optimization, compensation, age, driving, fitness to drive, gender

Introduction

During car driving, a driver must continuously adapt his behavior to the current task demands, taking into account his own capacities. This adaptive process becomes especially evident when a driver is challenged by internal (e.g. cognitive performance) or external (e.g. bad road conditions, complex driving situation) factors. Driving-relevant cognitive impairment becomes more prevalent with increasing age (Aksan *et al.*, 2012), creating the need for behavioral adaptations aimed at reducing the risk while driving. Others have shown that it is possible to reduce traffic-related risks associated with declining skills by adapting one's behavior in a risk-reducing way (De Raedt and Ponjaert-Kristoffersen, 2000). Therefore, driving-related behavioral adaptations represent an important factor that influences older drivers' traffic-related risk and has to be taken into consideration when it comes to evaluate cognition and fitness to drive in older drivers.

Baltes and Baltes (1990) conceptualized the "selective optimization with compensation"-model (SOC-model) to describe how individuals adapt their behavior when facing declining skills. In the context of driving and older drivers, the SOC-model has proved a useful theoretical framework in different contexts, e.g. to characterize changes in behavior after attending a driver education program (Nasvadi and Vavrik, 2007) or to describe the process of older drivers retiring from the road (Pickard *et al.*, 2009). According to the SOC-model, there are three different adaptive processes: selection, optimization, and compensation. Selection designates the abandonment of

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Table 1. Types of behavioral adaptations on different control levels

		BEHAVIORAL ADAPTATION (Baltes and Baltes, 1990)		
		SELECTION	OPTIMIZATION	COMPENSATION
Control level of driving behavior (Michon, 1979)	Tactical	E.g. change the route to avoid difficult situations.	E.g. turn off the radio when driving in complex situations.	E.g. ask a passenger to give directions.
	Strategic	E.g. avoid driving during rush hour.	E.g. checking the settings of rear and side mirrors.	E.g. buy a car with technical features that make up for reduced physical abilities (e.g. power-assisted steering).

goals and situations that exceed one's capacities and the adoption of new goals that lie within one's reach, e.g. avoiding driving during rush hours. Optimization indicates the improvement and optimal allocation of existing resources and skills, e.g. reducing distraction by conversations. Compensation refers to the acquisition and use of new methods and resources for reaching one's desired goals, e.g. getting a car with supporting features like power-assisted steering. The SOC-model, therefore, offers a useful framework to categorize different approaches to reduce traffic-related risks when facing constraints as drivers age (Table 1).

Adaptation behaviors can be further subdivided according to their temporal relation to the driving-task (Michon, 1979): Some actions and decisions are taken prior to driving (strategic level), while others occur during the drive itself (tactical level). Examples for decisions on the strategic level are which route to follow or not to drive during rush-hours. The tactical level includes decisions about speed, overtaking manoeuvers or whether to engage in distracting activities such as listening to the radio.

There is quite some research investigating driving-related behavioral adaptations of older drivers (Marottoli *et al.*, 1993; Hakamies-Blomqvist, 1994; De Raedt and Ponjaert-Kristoffersen, 2000; Baldock *et al.*, 2006; Trick *et al.*, 2010). Most studies in this field focus mainly on selection, finding that older drivers reduce the number of driving trips, avoid situations like driving in the dark and during rush hours, and tend to drive more slowly (Marottoli *et al.*, 1993; Hakamies-Blomqvist, 1994; Baldock *et al.*, 2006; Pickard *et al.*, 2009). The focus on selection implies a loss-centered view on older drivers' driving abilities, neglecting the possibility to optimize existing resources or to compensate for declining skills.

With regards to gender differences, research focused mainly on older age groups, finding consistently that older females tend to adopt more behavioral adaptations than older males (Charlton *et al.*, 2006; D'Ambrosio *et al.*, 2008; Molnar and Eby, 2008). It is well known that females of any age group, on average, tend to be more risk-avoiding in a variety of situations ranging from health choices (Rieker and Bird, 2005) to investment strategies (Hardies *et al.*, 2013) and driving (Harré, 2000; Windsor *et al.*, 2008). When it comes to driving, according to traffic accident statistics women are far less likely to be involved in crashes caused by risky driving-manoeuvers (Lourens *et al.*, 1999) and driving under the influence of alcohol (Fu, 2008), so differences in behavioral adaptations aimed at reducing the risk while driving may be expected.

The first aim of the present study was to create a questionnaire to assess driving-related behavioral adaptations aimed at reducing the risk while driving, with a focus on older drivers. The second aim was to explore age and gender differences using the newly developed questionnaire. For this purpose, the SOC-model (Baltes and Baltes, 1990) was used to generate items describing driving-related behavioral adaptations on the tactical and the strategic level (Michon, 1979). This approach was adopted as a rationale in order to make sure that all possible aspects of driving-related behavioral adaptations were considered and was not assumed as to be predictive for the factors underlying the items of the questionnaire. Since self-reports of behavior, as assessed in a questionnaire, are easily biased by socially desirable responding or stereotypes (Lajunen and Summala, 2003), items were created in a way to reduce biased responses. The questionnaire was administered to a mixed-gendered sample of older and younger drivers. In this pilot study, we focused on cognitively healthy drivers.

Table 2. Descriptive statistics (mean, standard deviations) for the items of the questionnaire regarding strategic and tactical selection

QUESTION (ITEM NUMBER)	TOTAL (N = 92) M (SD)	MALES (N = 46) M (SD)	FEMALES (N = 46) M (SD)	YOUNGER (N = 31) M (SD)	OLDER (N = 61) M (SD)
I avoided driving during rush hours (1)	0.72 (1.01)	0.70 (1.09)	0.76 (0.93)	0.48 (0.85)	0.84 (1.07)
I drove with heavy rain (17)	1.25 (1.02)	1.24 (1.02)	1.27 (1.05)	0.97 (0.71)	1.39 (1.13)
I drove in the dark (18)	1.90 (1.29)	1.89 (1.22)	1.87 (1.36)	2.39 (1.20)	1.66 (1.28)
I drove with bad road conditions (e.g. slickness) (19)	1.55 (1.25)	1.63 (1.22)	1.47 (1.31)	2.03 (1.11)	1.31 (1.26)
I drove while it was snowing (29)	1.80 (1.48)	1.87 (1.42)	1.78 (1.55)	2.10 (1.47)	1.66 (1.48)
I drove in the fog (30)	1.84 (1.43)	1.91 (1.38)	1.73 (1.50)	2.10 (1.51)	1.70 (1.38)
I refrained from driving because I did not feel well (34)	0.25 (0.69)	0.15 (0.63)	0.36 (0.74)	0.23 (0.76)	0.26 (0.66)
I followed a slow car because I did not dare taking over (2)	0.83 (0.78)	0.59 (0.65)	1.09 (0.82)	0.68 (0.60)	0.90 (0.85)
I voluntarily gave right of way (3)	0.93 (0.82)	0.80 (0.65)	1.07 (0.96)	0.94 (0.93)	0.93 (0.77)
I did not take over because of low visibility (4)	0.88 (1.02)	0.76 (0.85)	1.02 (1.16)	0.71 (0.82)	0.97 (1.09)
I interrupted a drive because I did not feel well (33)	0.12 (0.33)	0.11 (0.31)	0.13 (0.34)	0.16 (0.37)	0.10 (0.30)

The frequency of the described behaviors was indicated by the participants on a five-point Likert scale ranging from "never" (0) to "more than ten times" (4) in a given period of time. The item number indicates the position of the item in the questionnaire.

Methods

Participants

Ninety-two adults were recruited by advertisements in local newspapers. The sample included 31 participants younger < 65 years (16 women, 15 men; mean age = 30.5 years; SD = 6.3; age range 23–55) and 61 participants ≥ 65 years (30 women, 31 men; mean age = 70.2 years, SD = 5.5 years; age range 65–87 years). Participants were required to hold a driver's license for at least 5 years and to have been driving during the last two years. Exclusion criteria for the study were cognitive impairment (montreal cognitive assessment (MoCA) score < 27, Nasreddine *et al.*, 2005), visual impairment (corrected far visual acuity < 0.5 degrees, near visual acuity < 0.8), or significant motor impairment (timed-up-and-go test > 12 s, Bischoff *et al.*, 2003). The study was carried out in accordance to the declaration of Helsinki and was approved by the local ethics board of the Canton Bern. The written informed consent was obtained from all participants prior to inclusion. No compensation was provided for participation.

Driving behavior adaptations questionnaire DBAQ

To evaluate behavioral adaptations, a questionnaire (driving behavior adaptations questionnaire, DBAQ) was created. In order to assess all relevant aspects of driving-related behavioral adaptations, item generation was informed by the SOC-model (Baltes and Baltes, 1990) applied to the strategic and tactical level (Michon, 1979) (Table 1). A review of the literature on differences in driving-related behavior between younger and older drivers was performed. Findings that referred to risk-reducing behavioral adaptations (Hakamies-Blomqvist, 1994; De Raedt and Ponjaert-Kristoffersen, 2000; Baldock *et al.*, 2006) were categorized according to our theoretical framework and adapted to be included in the questionnaire. Questions in English were translated to German. Items were phrased in a neutral way, in order not to evoke biased answers due to social-desirability or stereotypes. For example, instead of asking whether a person drives slowly, she was asked how often she gets overtaken by other cars. The resulting questionnaire contained 38 items. The questions referring to different kinds of behavioral adaptations (i.e. selection, optimization, compensation) and levels of control (i.e. strategic, tactical) were randomly ordered within the questionnaire (Tables 2–4). The distribution between the categories explained in Table 1 was as follows: seven items for strategic selection and four item for tactical selection (Table 2); five items for strategic optimization and four items for tactical optimization (Table 3); nine items for strategic compensation and nine items for tactical compensation (Table 4). Different quantities of items in the single categories are inherent to the different types of adaptations under consideration. For example, there are more situations that can be avoided (selection) than

Table 3. Descriptive statistics (mean, standard deviations) for the items of the questionnaire regarding strategic and tactical optimization

QUESTION (ITEM NUMBER)	TOTAL ($N = 92$) M (SD)	MALES ($N = 46$) M (SD)	FEMALES ($N = 46$) M (SD)	YOUNGER ($N = 31$) M (SD)	OLDER ($N = 61$) M (SD)
I checked the settings of side and rear mirrors (9)	1.29 (1.35)	1.30 (1.26)	1.29 (1.46)	1.06 (1.15)	1.41 (1.43)
I turned down drinking alcohol because I had to drive (13)	1.92 (1.53)	1.54 (1.43)	2.31 (1.56)	1.58 (1.26)	2.10 (1.63)
I took sunglasses with me in order not to get glared (27)	1.53 (1.63)	1.15 (1.49)	1.87 (1.69)	0.87 (1.28)	1.87 (1.70)
I drove with a broken light (28)	0.55 (1.13)	0.43 (1.05)	0.69 (1.22)	0.65 (1.08)	0.51 (1.16)
I did not drive after taking medications (38)	0.02 (0.21)	0.00 (0.00)	0.04 (0.30)	0.06 (0.36)	0.00 (0.00)
I interrupted a conversation with a passenger because driving required my attention (24)	1.05 (0.97)	0.96 (0.94)	1.18 (0.98)	0.84 (0.73)	1.16 (1.05)
I turned off the radio in a complex driving situation (26)	1.00 (1.24)	0.85 (1.23)	1.18 (1.25)	0.71 (0.94)	1.15 (1.35)
I removed all the condensation from the car windows before starting to drive (31)	1.88 (1.47)	1.63 (1.44)	2.18 (1.45)	1.32 (1.28)	2.16 (1.49)
I removed all the ice from the car windows before starting to drive (32)	2.20 (1.51)	1.98 (1.42)	2.47 (1.56)	2.16 (1.32)	2.21 (1.61)

The frequency of the described behaviors was indicated by the participants on a five-point Likert scale ranging from "never" (0) to "more than ten times" (4) in a given period of time. The item number indicates the position of the item in the questionnaire.

there are ways to improve available resources (optimization). Respondents had to indicate for each item, how often they showed the behavior under consideration in a given period of time (e.g. during the last two weeks). A five-point Likert scale ranging from "never" (0) to "more than ten times" (4) was used to register the frequency. The administration of the questionnaire took about 12 min. The questionnaire was administered in German (English translation of the items in Tables 2–4). To ascertain clarity of the items and the scale, a first version of the questionnaire was administered in a pilot test to a sample of 15 young drivers (9 women, 6 men; mean age = 26.4 years; SD = 2.3; age range 23–32) and then revised accordingly.

Statistical analysis

Appropriateness of performing a factor analysis on the set of data was confirmed by the Bartlett's test for sphericity ($\chi^2 = 2{,}065.8$, $p < 0.001$) and the Kaiser–Meyer–Olkin measure of sampling adequacy (0.71). A factor analysis (principal component analysis with varimax rotation) was then calculated to extract the factors of the questionnaire and determine their properties. Since only one person reported not having driven after taking medication, this item was excluded from the factor analysis because of its too small variance. The reliability (internal consistency) of the extracted factors was calculated using Cronbach's α. To build the total score of a factor, scores of the individual items included in the factor were summed up. Group differences on global scores were calculated using Student's (equal variances) or Welch's (unequal variances) t-Test. Because of the high number of group comparisons on the level of single questionnaire items, corrections for alpha-errors (family-wise errors) seemed appropriate. Therefore, global age and gender effects on the items of the questionnaire were explored by submitting item scores to a multivariate analysis of variance (MANOVA) with age (younger, older) and gender (male, female) as between-subjects factors. Homogeneity for between-subjects analyses was tested with Box's M-test and normal distribution was tested with Shapiro–Wilk test. In case of significant omnibus effects in the MANOVA, group differences were then explored using univariate analysis of variance (ANOVA) with age (younger, older) and gender (female, male) as between subjects-factors. Homogeneity of variances for the ANOVA was tested with the Levene test. For variables that did not meet the conditions for MANOVA or ANOVA, groups were compared using Mann–Whitney U-Test. Critical p-values were corrected using the Bonferroni procedure. Reported p-values are two-sided. A p-value < 0.05 was considered as to indicate statistical significance, unless a Bonferroni-correction was applied. SPSS software (version 20) was used for statistical analyses.

Table 4. Descriptive statistics (mean, standard deviations) for the items of the questionnaire regarding strategic and tactical compensation

QUESTION (ITEM NUMBER)	TOTAL ($N = 92$) M (SD)	MALES ($N = 46$) M (SD)	FEMALES ($N = 46$) M (SD)	YOUNGER ($N = 31$) M (SD)	OLDER ($N = 61$) M (SD)
I planned when to have breaks before starting for a long drive (11)	0.60 (1.03)	0.39 (0.71)	0.82 (1.25)	0.16 (0.37)	0.82 (1.18)
I planned the route for a trip in advance (12)	1.34 (1.30)	1.15 (1.03)	1.56 (1.50)	1.10 (1.04)	1.46 (1.40)
I forgot where I parked my car (16)	0.51 (1.05)	0.43 (0.98)	0.60 (1.14)	0.32 (0.54)	0.61 (1.23)
When planning a trip, I chose the route with the lowest traffic density (20)	0.76 (1.00)	0.54 (0.84)	0.98 (1.12)	0.52 (0.68)	0.89 (1.11)
I chose to drive on a street with oncoming traffic instead of a highway (21)	0.78 (1.06)	0.78 (1.05)	0.80 (1.08)	0.58 (0.99)	0.89 (1.08)
I chose a rural route instead of an urban route (22)	0.54 (0.99)	0.65 (1.22)	0.44 (0.69)	0.32 (0.83)	0.66 (1.05)
I took a passenger with me to support me during a demanding drive (23)	0.27 (0.76)	0.13 (0.45)	0.42 (0.97)	0.19 (0.65)	0.31 (0.81)
I took turns at the wheel with another passenger on a long drive (36)	0.67 (1.09)	0.54 (0.98)	0.82 (1.19)	0.81 (1.17)	0.61 (1.05)
I thought about buying a car with features (automatic transmission, power-assisted steering, etc.) that facilitate the driving task (37)	0.32 (0.78)	0.26 (0.77)	0.38 (0.81)	0.23 (0.76)	0.36 (0.80)
I did not know the speed limit and guessed based on the appearance of the road (5)	0.66 (0.82)	0.52 (0.72)	0.82 (0.89)	0.74 (0.68)	0.62 (0.88)
I did not know the speed limit and adapted the speed to the other cars (6)	0.75 (1.01)	0.65 (0.99)	0.87 (1.01)	0.74 (0.82)	0.75 (1.09)
I was overtaken on a rural road (7)	1.27 (1.20)	1.11 (1.10)	1.44 (1.29)	0.84 (1.16)	1.49 (1.16)
I braked because the distance to the preceding car seemed too short (8)	1.42 (1.06)	1.46 (0.94)	1.38 (1.19)	1.29 (0.97)	1.49 (1.10)
I was overtaken on an urban road (10)	0.50 (0.90)	0.43 (0.65)	0.56 (1.10)	0.32 (0.70)	0.59 (0.97)
I had to take a detour after losing the right way (14)	0.90 (1.04)	0.61 (0.95)	1.20 (1.06)	0.84 (0.69)	0.93 (1.18)
I could not read a traffic sign because I was driving too fast (15)	0.47 (0.83)	0.30 (0.73)	0.64 (0.91)	0.35 (0.61)	0.52 (0.92)
I did not keep enough distance to the preceding vehicle when driving with bad road conditions (e.g. slickness) (25)	0.93 (1.14)	1.02 (1.14)	0.87 (1.14)	0.71 (0.74)	1.05 (1.28)
A passenger supported me during a drive by giving directions (35)	0.90 (1.01)	0.67 (0.67)	1.16 (1.22)	1.13 (1.02)	0.79 (0.99)

The frequency of the described behaviors was indicated by the participants on a five-point Likert scale ranging from "never" (0) to "more than ten times" (4) in a given period of time. The item number indicates the position of the item in the questionnaire.

Results

Factor analysis of questionnaire items

Items were then submitted to a factor analysis (principal component analysis with varimax rotation). The result of this analysis as indicated by the scree test (figure 1) was a two factor solution that explained 36.2% of the total variance. Factor loadings (rotated solution) for the 37 items are presented in Table 5. Factor loadings < 0.1 are omitted for clarity.

The first factor had an eigenvalue of 7.5 and consisted of 24 items. Its internal consistency (Cronbach's α) was 0.89. A content analysis of the items showed that it mainly included items concerning the driver himself, the vehicle or choices regarding the route. Namely, it included all items that describe actions aimed to make optimal use of one's physical and mental abilities by removing disturbing factors, e.g. wearing sun-glasses to reduce glare, checking the setting of side and rear mirrors, freeing the car windows completely from ice and condensation, turning off the radio in complex traffic situations, not driving after the consumption of alcohol or when not feeling well. Strategic measures to avoid complex and risky routes also loaded high on this factor, e.g. choosing a route with low traffic density, avoiding driving

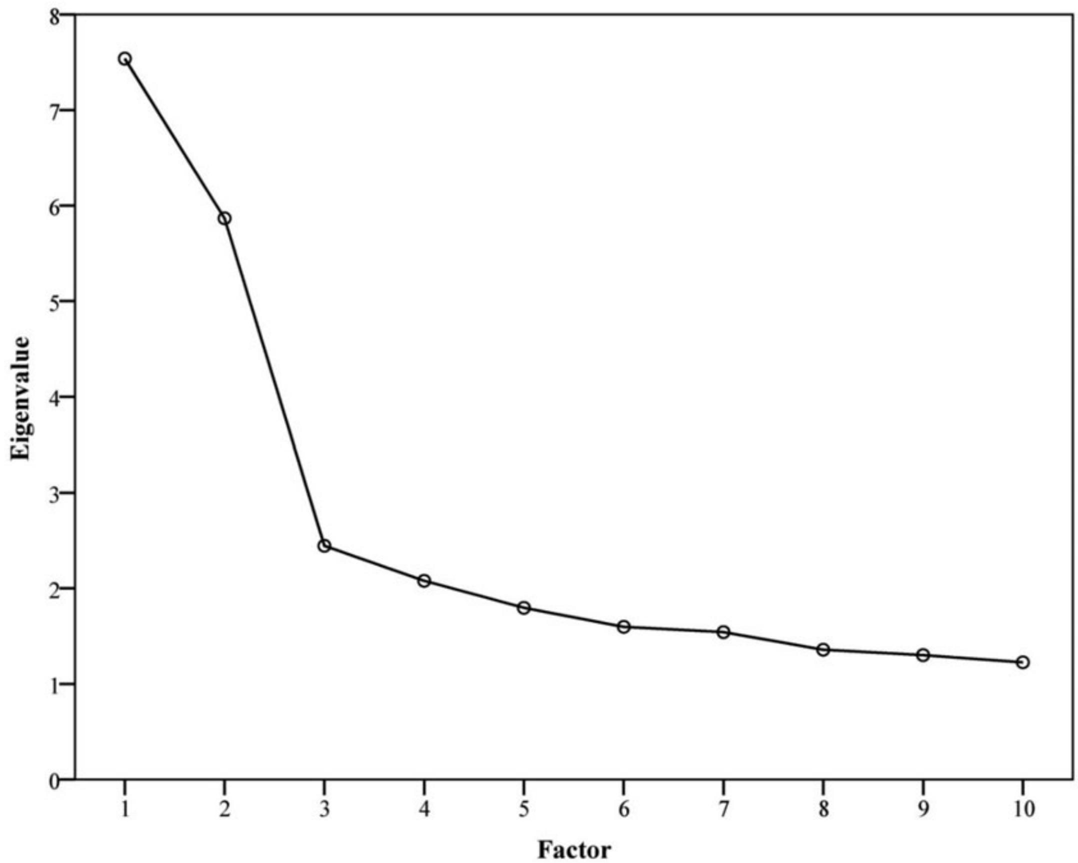

Figure 1. Scree plot for the first ten factors extracted from the DBAQ. Factor 1 includes items that describe behaviors aimed at reducing the risk while driving. Factor 2 includes items that describe behaviors that increase the risk while driving.

on in inner-cities. Measures taken before starting or during the drive to compensate for physical or mental deficits as a driver (e.g. getting tired, not being able to process information fast enough, not having enough physical strength) are also included in this factor, e.g. driving slowly, having a passenger to give directions, planning breaks in advance, taking turns at the wheel with a passenger, having a car with features that physically facilitate the driving task (power-assisted steering, etc.).

The second factor included 13 items with an eigenvalue of 5.9 and an internal consistency (Cronbach's α) of 0.87. Participants who scored high on this factor did not apply any kind of behavioral adaptations when facing dangerous or difficult driving conditions that are beyond the person's own control, e.g. weather, road conditions. On a strategic level, participants with high scores on this factor used to drive even in heavy rain, snow, fog and in the dark. On a tactical level, participants scoring high on this factor, for example, did not pay attention to keeping enough distance to the preceding vehicle when driving on slippery roads, they preferred driving on streets with oncoming traffic rather than on safer highways, and they did not adapt their speed according to visibility conditions or requirements of the driving task.

As expected, there was no correspondence between the categories in our model shown in Table 1 and the two factors resulting from the factor analysis.

Age differences in behavioral adaptations

Comparison of the total score of the two factors revealed significantly higher scores for older drivers than for younger drivers on the risk-reducing factor 1 ($t(84.5) = 2.21, p = 0.013$) but no age differences for the risk-increasing factor 2 ($t(90) = 0.29, p = 0.776$).

To investigate which specific behaviors the groups differ on, a MANOVA was calculated. The omnibus effect for age was significant (Pillai-Spur $= 0.43$, $F(13, 77) = 4.52$, $p < 0.001$), allowing subsequent analyses of the single items. Between-subjects analyses on the level of single items showed that younger and older participants differ with regards to several of the behaviors described. As for the items associated with the risk-reducing factor 1, older participants reported being overtaken

Table 5. Factor loadings (rotated solution) for the two factors of the DBAQ

QUESTION (ITEM NUMBER)	FACTOR 1	FACTOR 2
Passenger support (23)	0.716	– 0.113
Breaks (11)	0.666	– 0.133
Route planning (12)	0.662	– 0.153
Not driving when not well (34)	0.657	
Rush-hours (1)	0.618	
Passenger giving directions (35)	0.606	
Modern car (e.g. power-assisted steering) (37)	0.563	
Route with low traffic density (20)	0.546	
Interrupting conversations (24)	0.545	– 0.246
Taking turns at the wheel (36)	0.528	– 0.101
Stop driving when not feeling well (33)	0.493	0.152
Not overtaking slow car (2)	0.492	
Extra-urban instead of urban roads (22)	0.483	
Turning down the radio (26)	0.449	
Giving right of way (3)	0.422	0.141
Wearing sunglasses (27)	0.389	
Not taking over with low visibility (4)	0.191	
Getting overtaken on urban roads (10)	0.180	0.111
Checking settings of mirrors (9)	0.159	
No alcohol before driving (13)	0.376	
Getting overtaken on rural roads (7)	0.240	0.127
Adapting speed to other cars (6)	0.143	
Adapting speed to the appearance of the road (5)	0.127	
Removing ice from windows (32)	0.430	
Removing condensation from windows (31)	0.490	
Forgetting where the car parked (16)		0.860
Getting lost (14)		0.835
Driving with broken light (28)		0.826
Not enough distance on slippery road (25)		0.742
Two-way road instead of highway (21)		0.734
Driving in heavy rain (17)	– 0.140	0.656
Driving with bad road conditions (19)	– 0.323	0.590
Driving in the dark (18)	– 0.235	0.526
Not keeping enough distance (8)		0.150
Too fast to read traffic sign (15)		0.229
Driving when snowing (29)	– 0.119	0.488
Driving in fog (30)	– 0.167	0.389

Item numbers denote the item position in the questionnaire. Factor loadings < 0.1 are omitted for clarity.

more often, which indicates that they drive more slowly than younger participants ($F(1, 89) = 6.73$, $p = 0.011$). When going on a longer trip, older participants planned more often in advance when to have breaks ($U(31, 61) = 1{,}267.5$, $p = 0.002$). They also took their sun-glasses with them more often than young participants in order not to get glared ($U(31, 61) = 1{,}247.5$, $p = 0.009$) and made sure that the car window be completely free from ice and condensation ($F(1, 89) = 7.62$, $p = 0.007$).

Although the total score of the risk-increasing factor 2 did not differ between age groups, there were some differences in specific behaviors included in this factor. Younger participants reported significantly less avoidance of driving in the dark ($F(1, 89) = 6.93$, $p = 0.010$) and with bad road conditions ($U(31, 61) = 598.0$, $p = 0.003$) than older participants.

Gender differences in behavioral adaptations

A t-Test for independent samples revealed significant gender differences for the risk-reducing factor 1, with females showing significantly more behaviors aimed at reducing the risk while driving ($t(90) = 2.52$, $p = 0.014$). No gender differences were found for the risk- increasing factor 2 ($t(90) = 0.45$, $p = 0.656$).

To explore differences in specific behaviors, single item scores were first submitted to a MANOVA and significant global gender differences were found (Pillai-Spur = 0.29, $F(13, 77) = 2.39$, $p = 0.010$). Subsequent between-subjects analyses on the level of single items revealed significant gender differences for several behavioral adaptations. Among the items associated with the risk-reducing factor 1, females preferred more often than males following a slow-travelling car rather than performing a risky take-over manoeuver ($F(1, 89) = 9.79$, $p = 0.002$). When planning a trip, females chose the route with the lowest traffic density more often than males did ($F(1, 89) = 7.90$, $p = 0.006$). Females also restricted their alcohol consumption before driving more than males ($F(1, 89) = 6.32$, $p = 0.014$). As for the items of the risk-increasing factor 2, only the frequency of "having to take a detour after losing the right way" differed between gender groups, with females reporting losing the right way more frequently ($U(46, 46) = 1{,}458.5$, $p = 0.001$).

Discussion and conclusions

In the present study, the DBAQ was created and tested in a mixed-gender sample of older and younger participants to explore age and gender differences in driving-related behavioral adaptations. Item generation followed a theory-driven approach (Michon, 1979; Baltes and Baltes, 1990) and biasing influences of stereotyping and impression management were avoided if possible (Lajunen and Summala, 2003). Two independent factors were extracted from the questionnaire. The first factor included behaviors aimed at actively reducing the risk while driving, the second factor included items that described the lack of behavioral adaptations when facing dangerous or complex situations. The two factors had high reliability (Cohen, 1988).

Group comparisons revealed significant age and gender differences in behavioral adaptations. Older drivers scored significantly higher on the risk-reducing factor 1, indicating that they showed risk-reducing behaviors more frequently than younger drivers. No difference was found for the risk-increasing factor 2. Group comparisons on the level of specific behaviors revealed that older participants took more measures to make their trips less physically and cognitively demanding. In line with the existing literature (Hakamies-Blomqvist, 1994; Baldock *et al.*, 2006), older drivers reported selecting their driving exposure in order to avoid risky situations (e. g., driving in the dark, with bad road conditions) more often than younger drivers. Before starting for a trip, they planned when to have breaks in order to compensate for reduced forces. They also reported driving more slowly. Driving with slower speed than younger drivers is a known compensatory behavior adopted by older drivers (Hakamies-Blomqvist *et al.*, 1999; Trick *et al.*, 2010) that has not been corroborated in a study based on self-reports so far. Existing studies on behavioral adaptations focused mainly on selection, neglecting optimization, and compensation (Hakamies-Blomqvist, 1994; Baldock *et al.*, 2006; Trick *et al.*, 2010). This approach implies a loss-centered view on older drivers' driving abilities. Our findings show that older drivers do use behavioral adaptations aimed at optimizing existing resources and compensating for existing deficits more than younger drivers. This highlights the possibility to make up for existing deficits, allowing for a resource-oriented view on older drivers' driving abilities. Results also indicate that with a questionnaire like the DBAQ possibilities for improvement in behavioral adaptations of older drivers can be identified. In this study, no older participant reported not driving after taking medications, although about 20% of community-dwelling people over 65 years of age take psychotropic medication (Aparasu and Mort, 2004; Naughton *et al.*, 2006) and research consistently supports an increased risk of crashes for older drivers taking psychotropic medications (Lococo and Staplin, 2006). However, the item that was used in this questionnaire ("I did not drive after taking medications") is difficult to interpret since some medication potentially impairs driving (i.e. psychotropic medications, some pain killers), while others may enable safe driving (e.g. medication for epilepsy, to treat diabetes). Furthermore, most medications are used to alleviate symptoms (e.g. of depression or diabetes) potentially interfering with driving performance. We therefore, propose to modify the item to "I did not drive after taking medications, which impair driving performance."

The comparison of women and men also revealed differences in behavioral adaptations, with women showing more behaviors described by items included in the risk-reducing factor 1. When planning a trip, females avoided complex traffic situations more often than men and turned down drinking alcohol more often than men when they had to drive. On a tactical level, women reported more frequently compared to men avoiding risky driving maneuvers. Again, no overall differences were found in questions included in the risk-increasing factor 2. These findings confirm very well the picture that emerges from traffic accident statistics and related research. For example, Fu (2008) analyzed traffic accident statistics and found male gender to be a major risk factor for driving under the influence of alcohol. Lourens *et al.* (1999) reported significantly more violations due to risky driving manoeuvers for males. These gender differences found with data from sources that are not based on self-reports (i.e. road traffic statistics) are also reflected in the results of the DBAQ. Therefore, the DBAQ seems to be able to capture relevant differences in driving-related behavioral adaptations. This is especially important, since the DBAQ is based on self-reported behavior and, therefore, answers are easily biased by socially desirable responding, impression management or stereotypes (Lajunen and Summala, 2003). As our results suggest, these response tendencies can be reduced by adequate phrasing of questions.

An interesting question is whether the behavioral adaptations assessed in this study are the consequence of an accurate awareness of one's capacities and limitations or rather the result of lifestyle changes (e.g. retirement). In this study, we did not assess underlying motives for behavioral adaptations or subjective driving skills, but findings from studies on the relationship between self-awareness (Marottoli *et al.*, 1998; Freund *et al.*, 2005; MacDonald *et al.*, 2008; Ross *et al.*, 2012), actual driving skills (Eby *et al.*, 2003; Molnar *et al.*, 2008; Okonkwo *et al.*, 2008), and self-regulation (De Raedt and Ponjaert-Kristoffersen, 2000; Stalvey *et al.*, 2000; Baldock *et al.*, 2006; Charlton *et al.*, 2006; Molnar *et al.*, 2008; Okonkwo *et al.*, 2008) can contribute to answer this question. It is well established that older drivers tend to restrict their driving (e.g. avoidance of drives at night or with bad weather conditions) (Hakamies-Blomqvist *et al.*, 2005; Langford *et al.*, 2006; Vance *et al.*, 2006). These findings are in line with the age differences that emerged from our study. However, studies of Bhatti *et al.* (2008), Jette *et al.* (1992), and Stalvey *et al.* (2000) indicate that these behavioral adaptations are not always primarily aimed at reducing risks, but sometimes rather a consequence of lifestyle changes (e.g. less work-related driving), and that situations that are avoided most frequently (e.g. parallel parking) are not necessarily the ones with highest risks for serious crashes or physical harm (Baldock *et al.*, 2006; Donorfio *et al.*, 2008; Molnar *et al.*, 2008).

The aim of this study was to explore age and gender differences in behavioral adaptations with the newly created DBAQ following a theory-driven, systematic approach. The focus lay on the specific situation of older drivers. Participants in this study were all cognitively unimpaired, so reported findings may not yet be generalized to other groups, such as persons with cognitive impairment or dementia. As impaired patients are an important target group for the assessment of risk-reducing behavioral adaptations, this will be addressed in future studies. The questionnaire shows good consistency with existing research and is ready for use in further research to address the limitations of the present study (e.g. limited sample size, cross-sectional data). Of special interest is the relationship between behavioral adaptations and indicators of real driving (e.g. crashes, fines, violations) in older drivers, which will be addressed in future studies. Focusing not on deficits but on ways to cope with deficits, enables a more resource-oriented approach in the evaluation of selection, optimization, and compensation in older drivers.

Conflict of interest

None.

Description of the author's roles

All authors contributed to the research questions and study design. The study was carried out and the data were analyzed by the first author. The manuscript was written and revised as a collaboration of all authors.

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