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Driving simulation test for evaluating hazard perception: Elderly driver response characteristics

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ABSTRACT

We created a driving simulation test for assessing drivers' hazard-perception skills by measuring their palmar sweating response (PSR), skin potential reflex (SPR), and ability to operate the steering wheel, accelerator, and brake. We recruited 52 elderly people who were aged ≥60 years and were active drivers. These participants undertook the driving simulation test, and we measured their PSR, SPR, and device operation responses. PSR tended to be greater in hazard scenes that involved anticipation or complexity processes, suggesting the involvement of factors such as the participants' readiness to anticipate hazards and their emotional changes. SPR response was faster in hazard scenes that involved a surprise process. SPR response was faster than braking response, except in scenes where the participants had only a fleeting moment to react to the hazard, suggesting that SPR is a suitable evaluation index for hazard perception timing. Two participants were suspected of having decreased cognitive function according to the Mini-Mental State Examination. These individuals exhibited PSR and SPR responses that were not consistent with the hazard scenes, and they made errors in their operation of the driving simulator. These findings highlight the need to examine the impact of decreased cognitive function on hazard perception.

1. Introduction

In recent years, the number of car accidents involving the elderly has been increasing and this has become a problem that must be addressed by society. The cases of car accidents involving elderly drivers is usually considered to be a decrease in mental and physical functioning in such individuals. In addition, many researchers have highlighted the existence of a relationship between driving ability and both visual attentiveness and cognitive function (Anstey, Horswill, Wood, & Hatherly, 2012; Anstey, Wood, Lord, & Walker, 2005; Horikawa, Morizono, Koga, & Horie, 2009; Innes et al., 2007; Ishimatsu, Miura, & Shinohara, 2010; Selander, Lee, Johansson, & Falkmer, 2011; Stutts, Stewart, & Martell, 1998). It is further known that in the early stages of Alzheimer's disease (AD), although individual differences are large, it is possible to continue driving for a relatively long period of time (more than a few years; Dubinsky, Stein, & Lyons, 2000; Duchek et al., 2003; Fox, Bowden, Bashford, & Smith 1997; Hunt, Brown, & Gilman, 2010; Ott et al., 2008). However, individuals with early AD demonstrate impaired on-road driving performance (Fox et al., 1997) and impaired simulated driving performance (Stein & Dubinsky,

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2011) when compared to healthy controls. Thus, a screening test that enables the detection of drivers who are at a risk of having accidents is being sought (Breen, Breen, Moore, Breen, & O'Neill, 2007; Lloyd et al., 2001).

Strategies to evaluate driving ability can be broadly divided into three categories: evaluation using neuropsychological tests, evaluation using driving simulators, and evaluation of driving skills on the road. As an example of a neuropsychological test, the Trail Making Test (TMT) may be used to measure attention, visual search capacity, information processing speed, and execution function (Freund, Colgrove, Petrakos, & McLeod, 2008; Horikawa et al., 2009; Stutts et al., 1998; Toyokura, Tanaka, Furukawa, & Murakami, 1996). In the meta-analysis conducted by Devos et al. (2011), TMT was suggested to be effective as a screening test for assessing driving capability. Regarding the evaluation of elderly drivers, the Mini-Mental State Examination (MMSE) is often used to measure cognitive function (Fox et al., 1997; Freund, Colgrove, Burke, & McLeod, 2005; Freund et al., 2008). Fox et al. (1997) performed an on-road driving evaluation and neuropsychological examinations and medical tests that were standardized to the elderly suspected of AD. They suggested that the MMSE is an effective predictor of driving skills of the elderly. In contrast, it has also been suggested that only cognitive function tests alone, including the MMSE, cannot determine the driving capability of elderly individuals with early-stage dementia (Iverson et al., 2010). Regardless, the evaluation of driving ability using neuropsychological tests has limitations.

Driving simulation tests are also used to ascertain driving skills and have the advantage of allowing researchers to evaluate a driver's ability to operate the steering wheel, accelerator, and brake (Freund et al., 2005; Lee, Cameron, & Lee, 2003; Andrews & Westerman, 2012; Fildes, Charlton, Muir, & Koppel, 2007; Stein & Dubinsky, 2011). Driving ability has been evaluated using a combination of desktop tests (TMT and MMSE) and driving simulation tests (Dubinsky et al., 2000; Duchek et al., 2003; Fildes et al., 2007; Freund et al., 2005; Freund et al., 2008; Lee, Lee, & Cameron, 2003; Lee, Lee, Cameron, et al., 2003; Lee, Cameron, & Lee, 2003). To evaluate driver skill, it is necessary to assess hazard-prediction abilities and vehicle operation skills. Driving simulation tests are more realistic than desktop neuropsychological tests in these respects, and they are also cheaper and more efficient than evaluations of on-road driving (Lee, Lee, Cameron, et al., 2003). Therefore, driving simulation tests will be of increasing importance in traffic-safety promotion centers, wherein the elderly renew their driver's licenses, and in medical facilities wherein cognitive-function tests are conducted.

1.1. Hazard-perception skills

Hazard perception is the process of responding to dangerous events on the road that could lead to a traffic accident (Crundall, Chapman, et al., 2012). It is defined as "the ability to read the road and anticipate forthcoming events" (McKenna, Horswill, & Alexander, 2006). A Personal computer (PC) -based hazard-perception test has already been developed and used in the UK and Australian driver licensing systems. In this hazard-perception test, operating a simulated vehicle is not required, and therefore subjects can concentrate on identifying hazard scenes from video clips. In the PC-based hazard-perception test, since all subjects encounter the same hazard scenario, it is possible to objectively evaluate responses to the hazard. However, when compared with an on-road test, the hazard-perception test has limitations, such as lower realism, reduced field-of-view, and the inability to measure device operation (Wetton, Hill, & Horswill, 2011).

Hazard perception (HP) is associated with processes such as "*anticipation,*" "*surprise,*" and "*complexity*" (Crundall, Chapman, et al., 2012; Sagberg & Bjørnskau, 2006) . *Anticipation* refers to the ability to infer the future occurrence of a hazard. In the research evaluating anticipation capacity, video clips taken from the driver's perspective have been used, and gaze and reaction time during the simulated driving have been evaluated (Borowsky, Shinar, & Oron-Gilad, 2010; Crundall, Crundall, Clarke, & Shahar, 2012; Crundall, Chapman, et al., 2012; Lehtonen, Lappi, Kotkanen, & Summala, 2013; Meir, Borowsky, & Oron-Gilad, 2014; Sagberg & Bjørnskau, 2006) . Young novice drivers are more prone to crash because their skills of hazard prediction are worse than those of experienced drivers (Garay, Fisher, & Hancock, 2004; Smith, Horswill, Chambers, & Wetton, 2009). However, a video clip that suddenly presents the hazard of a volleyball in front of the vehicle has the potential to *surprising* both novice and experienced drivers; this event cannot be predicted. Moreover, in this case, young novice drivers may show faster reaction times than experienced drivers (Gottsdanker, 1982). Concept of *complexity* is concerned with the driver's ability to monitor multiple sources of potential threat in a complex and dynamic environment (Crundall, Chapman, et al., 2012; Sagberg & Bjørnskau, 2006). In situations where it is necessary to pay attention simultaneously or sequentially to a plurality of hazards, effective visual search is required of the driver. In young novice drivers, the ability to pay attention to multiple potential risks may be less developed than in experienced drivers.

In the case of the elderly drivers, it has been suggested that self-evaluation of hazard-perception skill is related to self-regulation of driving (Horswill, Anstey, Hatherly, Wood, & Pachana, 2011). For this reason, in an elderly driver, feelings of anxiety and decreased self-confidence (Gwyther & Holland, 2012), as well as discomfort (Meng & Siren, 2012) are emphasized.

1.2. Biological indicators that reflect hazard-perception skills

Palmar sweating response (PSR) and electrodermal activity (EDA) can be observed when people feel they are in danger or are surprised. PSR is also referred to as mental sweating or emotional sweating (Kuno, 1956). PSR can be caused by tension or emotional excitement, and it can also be promoted by higher nervous activity, such as that induced by mental arithmetic. Furthermore, PSR instantly occurs when people "stand ready," such as when they are suddenly approached by a stranger or presented with a challenge (Ogawa, 1975; Kobayashi, Tomioka, Ushiyama, & Ohhashi, 2003). PSR also reflects skin