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Vigilance decrement during the on-the-road driving tests: The importance of time-on-task in psychopharmacological research

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ABSTRACT

Time dependent decrements in performance are characteristic of activities that are monotonous and require focused attention for an extended period of time. A vigilance task is a task that participants can perform without difficulty for a short period of time, but with time their performance becomes impaired. A real world example of such a vigilance task is prolonged highway driving. The on-the-road driving test in normal traffic was specifically designed to measure the effects of vigilance decrement associated with driving. The primary parameter of this test is the Standard Deviation of Lateral Position (SDLP), i.e. the weaving of the car. This methodological paper explains the typical vigilance decrement seen in the on-the-road driving test and discusses the importance of sufficient time-on-task to elucidate potential adverse drug effects on driving. Performance decrements (SDLP increment) as a function of time are seen after both drug and placebo treatment, following a similar pattern over distance/time traveled. However, whereas for some drugs SDLP differences between drug and placebo are constant, other drugs produce additional performance decrement that increases over distance traveled. It is concluded that driving tests of short duration (e.g. less than half an hour) may fail to detect drug-related impairment, because participants are capable of, at least in part, counteracting the impairment by increased effort and motivation to perform the test.

1. Introduction

Driver sleepiness is one of the most common causes of traffic accidents and crashes. It is estimated that up to 20% of crashes are sleep-related (Horne and Reyner, 1995), but often this percentage is underestimated because, especially during the day, policemen often not consider sleepiness as the primary cause of a crash (and thus not report sleepiness as the cause of the crash) (Pack et al., 1995). Vigilance decrement, i.e. a reduced a capability to perform as time on task progresses, is one of the consequences of the inability to maintain alertness and focused attention on the task at hand. Sedative effects of Central Nervous System (CNS)-drugs may cause driver sleepiness and subsequent performance decline. However, the effect is also seen under normal driving (placebo) conditions. During sustained highway driving maintaining alertness and unimpaired performance are essential. Therefore, research has been devoted to examine the effects of vigilance decrement on driving ability. The aim of this review paper is to summarize the current knowledge on vigilance decrement during driving, how CNS drugs affect vigilance decrement during driving, and to stress why vigilance decrement should be an essential feature of driving tests. This has been done by discussing classic examples from research applying the 100-km on-the-road driving test, conducted now for 30 years in The Netherlands (Verster and Roth, 2012a).

Driver sleepiness can be caused by various factors related to either the participants behavior (e.g. sleep deprivation) or health status (e.g. sleep apnea) or related to the task the participant performs (e.g. driving alone on a highway at night with low traffic density) (May and Baldwin, 2009). Various road-related factors have shown to significantly contribute to sleepiness-related crashes. For example, they are likely occurring on monotonous highways (Thiffault and Bergeron, 2003; Liu and Wu, 2009; Cerezuela et al., 2004; May and Baldwin, 2009).

When driving long distances, driving becomes progressively worse solely with duration of driving. This has been shown in participants after sustained wakefulness and in sleep deprived participants (Dawson and Reid, 1997; Powell et al., 2001). This may be especially dangerous in drivers who are not experienced in driving long distances, such as people who go on holiday. Moreover, they often combine sleep deprivation related to an early awakening and departure or night driving (down part of the circadian phase and a prolonged period of wakefulness), with long distance driving increasing the risk of having a sleepiness related crash (Philip et al., 1999a,b). In a monotonous highway driving simulator test,

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Table 1
Factors contributing to driver sleepiness and vigilance decrement.

Factor	Effect on vigilance decrement	References
Sleep deprivation	With sleep deprivation vigilance decrement is more pronounced	e.g. Powell et al. (2001), May and Baldwin (2009), Philip et al. (2005a,b), Connor et al. (2002), Liu et al. (2003), Dawson and Reid (1997)
Duration of wakefulness	With increased duration of wakefulness vigilance decrement is more pronounced	e.g. Pack et al. (1995), May and Baldwin (2009), Philip et al. (2005a)
Age of driver	with increasing age vigilance decrement is more pronounced	e.g. Pack et al. (1995), Horne and Reyner (1995), McConnell et al. (2003), Otmani et al. (2005a,b), Åkerstedt and Kecklund (2001), Anund et al. (2008a,b), Philip et al. (2004, 1999b), Sagberg (1999), Lowden et al. (2009), Lee et al. (2003)
Gender	Females may be more sensitive to vigilance decrement than men	e.g. McConnell et al. (2003), Åkerstedt and Kecklund (2001), Sagberg (1999)
Time of day	Vigilance decrement is more pronounced at night and in the afternoon (hours of increased sleep pressure)	e.g. Horne and Reyner (1995), McConnell et al. (2003), Gillberg et al. (1996), May and Baldwin (2009), Connor et al. (2002), Philip et al. (2006)
Time on task	Vigilance decrement is more pronounced with increasing time on task	e.g. Ting et al. (2008), Thiffault and Bergeron (2003), May and Baldwin (2009), Philip et al. (2005a, 1999a,b), Gillberg et al. (1996), Sagberg (1999), Lowden et al. (2009), Gimeno et al. (2006)
Task demands	Vigilance decrement is more pronounced in tasks with low task demands	e.g. Oron-Gilad and Ronen (2007), May and Baldwin (2009)
Monotony	Vigilance decrement is more pronounced in monotonous tasks	e.g. Thiffault and Bergeron (2003), Liu and Wu (2009), Cerezuela et al. (2004), May and Baldwin (2009)
Countermeasures	Countermeasures such as caffeine, napping reduce driver sleepiness and vigilance decrement	e.g. Anund et al. (2008a,b), Cummings et al. (2001), Reyner and Horne (1998)

performance was significantly worse when compared to the same test that included various stimuli along the road that attracted, and hence periodically changed the driver's attention (Thiffault and Bergeron, 2003). In the on-road driving methodology, prolonged time on task and accompanying performance decrement appears quite early during the 40-min monotonous driving test, and asymptotes after 20–25 min. Task demands (e.g. driving straight versus making turns, low versus high traffic density) and the effectiveness of countermeasures (e.g. caffeine consumption, pre drive naps, rest breaks) all play an important role in determining the magnitude of driver sleepiness and associated performance decrement. Table 1 lists some of the contributing factors to driver sleepiness that may result in performance decrement.

When designing a driving study, it is important to take the factors listed in Table 1 into account, because they al have a significant impact on the study outcome.

In addition to the factors listed in Table 1, adverse effects of CNS-drugs also contribute to driver sleepiness and performance decrement. Drugs that are capable of crossing the blood brain barrier may have sedative adverse effects. This may result in sleepiness and have a negative impact on performance. A classic example of such drugs are the benzodiazepines. These drugs are most commonly used for anxiolytic or hypnotic purposes. However, their sedative properties may compromise daily activities such as driving or job performance. It is well documented that these drugs produce sleepiness and increase the risk of becoming involved in a traffic accident (Verster et al., 2004, 2005).

2. The on-the-road driving test

To determine vigilance decrement (i.e. time dependent impairment) in driving, it is essential that a driving test is of sufficient duration and has a monotonous character. A driving test that is sensitive to vigilance decrement is the Dutch on-the-road driving test (O'Hanlon et al., 1982; Verster and Roth, 2011). The on-the-road driving test is a standardized 100-km test performed on a primary highway during normal traffic. It takes about 1 h to complete the test. An important factor for the incremental performance decrement with distance traveled is the fact that sustained attention is required that decays with time. Sustained attention is not only a requirement to perform the test according to the instructions, but also a necessity to ensure safety, since the driving test is performed in actual traffic. Participants are instructed to drive with a steady lateral position within the right traffic lane while maintaining a constant speed of 95 km/h (60 mph). For safety reasons, a licensed driving instructor who has access to dual controls sits in the right front seat and if necessary, he can intervene, or stop the drive if it becomes unsafe. A camera, mounted on the roof of the test vehicle, measures the vehicle's lateral position relative to the road delineation. The amount of weaving of the car, measured by the standard deviation of the lateral position (SDLP, cm), is the primary outcome parameter (see Fig. 1).

The Dutch on-road tests is generally performed in young adult healthy volunteers of mixed gender. The study set-up and test methodology is standardized and usually a double blind crossover design is used (Verster and Roth, 2011). Hence, many factors listed in Table 1 do not apply when the effects of CNS drugs are examined. For example, time of day, time on task, task demands, monotony are similar for each participant, and health status, age and gender are controlled for during the inclusion of participants.

The test has been shown to be sensitive to drug-induced dose-dependent impairment for alcohol, illicit drugs (Penning et al., 2010), and CNS-drugs such as hypnotics (Verster et al., 2004, 2006a), antidepressants (Ramaekers, 2003), antihistamines (Verster and Volkerts, 2004), and anxiolytics (Verster et al., 2005).

The highway driving test is intended to mirror real life driving circumstances and environment. For example, when hypnotic

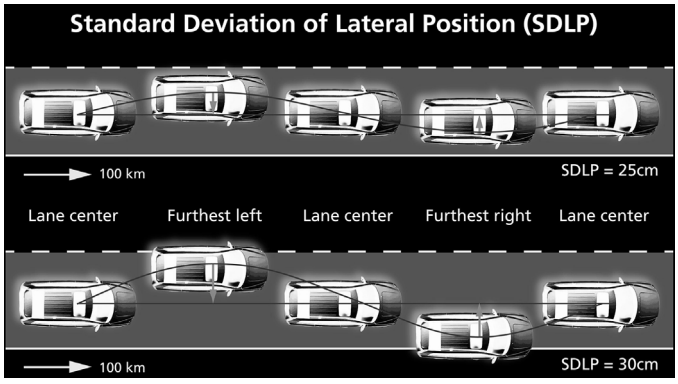

Fig. 1. Standard Deviation of Lateral Position (SDLP).