Sleepiness, Aging, and Driving Skills

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Sleepiness has been recognized as one of the main factors that affect driving skills. Sleepiness has been defined as difficulty maintaining wakefulness without external stimuli. Excessive daytime sleepiness (EDS) is present in 10–20% of the general population and negatively impacts reaction time, vigilance, and judgment of performance at the wheel. The sleepiness level can be evaluated by subjective or objective methods and may be influenced by poor sleep hygiene, circadian rhythm, or alcohol and drugs.

sleepiness drowsiness driving aging older adults EEG

1. Introduction

Driving is a crucial aspect of human functioning to keep a high quality of life and independence. The safety at the wheel is affected by multiple variables, such as visual abilities [1], attention and decision-making [2], age [3], and drowsiness [4].

Epidemiological observations revealed that young and adult drivers (aged 15–44 years) account for 48% of road traffic deaths worldwide [5], and road traffic injuries due to sleepiness are about 10–20% [6][7][8]. Recent trends indicate that motor vehicle incidents are among the top five causes of mortality by 2030 [5]. For this reason, in the last decades, the relationship between driving performance and sleepiness received growing attention [9][10]. The available literature showed that fatal road accidents provoked by a driver falling asleep at the wheel are more common among young individuals [6][11][12][13][14]. Nevertheless, almost 7000 older adults were involved in motor vehicle accidents in the USA, considering that it has been estimated that more than 40 million elderly drivers have a driving license [15]. Although the absolute number of crashes involving older drivers is currently low, we have to note that the percentage of older people with a driving license has grown by 34% in the last decade [15], and crash frequency per mile driven begins to increase at around 65 years of age [16]. Despite accounting for only 8% of miles driven per year, older drivers appear to be involved in 14% of crash fatalities [16]. In particular, Italian data [17] showed that the drivers more frequently involved in road accidents were those aged 20–29 years (18.3%) and 40–54 years (29.2%), with a growing percentage (9.2%) of elders (≥70 years). This issue may be related to a rise in bodily damages and liability claims for property damage, especially among 75 years or older subjects [18].

Prior studies ascribed reductions in geriatric driving skills to cognitive, visual, and/or physical impairments [2][16][19][20][21][22]. However, sleepiness and sleep-related complaints—which strongly affect the other functions—have been rarely investigated. Actually, sleep patterns undergo significant changes during aging [23]: advanced bedtime and wake up time, decreased total sleep duration, fragmented sleep, and a substantial reduction of the slow-wave sleep, consistently with the significant lowering of slow-wave activity (SWA) during NREM sleep in the quantitative EEG [24][25]. Further, evidence highlighted older adults reported high rates of sleep disturbances, and approximately 20–30% of elderly people experience EDS [24]. Some authors hypothesized that older adults try to self-regulate their driving [2]. In other words, they avoid driving in high-risk settings, e.g., peak traffic times and dark conditions (e.g., [25][26]), which may contribute to reducing the consequences of their EDS and poor sleep quality.

It should be noted that by 2050 the proportion of the world's population over 60 years will nearly double [27], and a better understanding of the complex relationship between sleepiness/vigilance degree, aging, and driving performance is becoming increasingly important.

2. Age-Related Effect of Sleepiness on Driving Performance

2.1. Self-Reported Sleepiness

The project by Vaz Fragoso and colleagues produced three studies on longitudinal data collecting from a sample of 430 older adults (≥70 years) [28][29][30]. They aimed to assess the relationship between drowsiness/sleep complaints and driving capacity. Both sleepiness and driving measures were self-reported in all studies [28][29][30]. Moreover, other sleep questionnaires to evaluate insomnia and sleep apnea risk were administered. Older adults had chronic disturbances, e.g., diabetes and hypertension, while a small part of the sample reported sleep apnea. As assessed by the Epworth sleepiness scale (ESS) [31], subjective sleepiness was related both to sleep apnea risk and chronic disease.

In a second study, the authors assessed the longitudinal association between sleep disturbances and adverse driving events in the same cohort of older adults [29]. Longitudinal evaluations of these episodes (i.e., crash or traffic infraction and near-crash or getting lost) were planned every six months for two years. Overall, 418 older drivers participated in the follow-up. Among the participants, 215 older drivers had at least one crash, traffic infraction, near-crash, or getting lost. Crashes appeared to be correlated with a traffic infraction and near-crash with getting lost. Subjects with these adverse events showed at the baseline higher ESS scores and greater driving frequency than older adults not experiencing these events at the wheel. However, it should be noted that the median ESS score was not clinically relevant [29].

Moreover, sleep disturbances did not significantly affect the odds of having adverse driving events [29]. In a third article, Vaz Fragoso and colleagues evaluated the relationship between sleep disturbances at the baseline and the subsequent driving cessation over a two-years period [30]. Results revealed that insomnia, daytime sleepiness, and sleep apnea risk were not longitudinally associated with driving cessation.

Moreover, AMT significantly advantaged the younger group who made more driving errors than older drivers during the first and second monotonous segments. Older adults did not show increased mistakes with fatigue. Surprisingly, AMT did not negatively impact their driving performance. However, they showed increased speed variability when driving with AMT [32].

2.2. Behavioral Task

Leufkens et al. [33] and Bartolacci et al. [34] used the psychomotor vigilance task (PVT) [35] as an instrument to assess psychomotor vigilance. The PVT is based on a simple visual reaction time test and is generally accompanied by a self-reported sleepiness rating (e.g., Karolinska sleepiness scale—KSS [36]). The study by Leufkens et al. [37] involved 63 subjects with 50–75 years who were subdivided into three groups: insomnia group with medications, insomnia group without medications, and healthy subjects. All participants performed the highway driving test [38], measuring tracking road performance. The standard deviation of lateral position (SDLP) was used as an index of individual driving performance. Moreover, other tasks were administered to assess driving-related skills (e.g., selective attention, decision making, stimulus interpretation, speed, and adaptive motor response to driving events; divided attention). A preliminary sleep assessment with polysomnography was performed, not finding differences between groups. Subjective sleepiness and sleep complaints were also assessed. Older good sleepers and older insomniacs did not differ in driving performance and driving-related skills, as well as in PVT performance. Reaction times at the PVT differed only between morning and evening performance [33]. Indeed, mean reaction time in the PVT was faster in the morning than the evening in controls, but not in subjects with insomnia.

More recently, Bartolacci et al. [34] compared 40 healthy older adults with 40 young subjects. Along with the subjective assessment of sleep quality and self-reported sleepiness, the PVT was administered to collect a behavioral sleepiness evaluation. Moreover, driving-related skills were tested: selective attention, tachistoscopic perception (e.g., the ability to obtain an overview, the skills about visual orientation, and the perceptual speed), and the risk assumption. Older adults reported lower sleep efficiency and worse performance in PVT (tendency to make more mistakes and slowing reaction times in the 10% of fastest responses) than the younger group.

2.3. Electrophysiological Pattern

Campagne et al. [39], Lowden et al. [40], and Filtness et al. [37] assessed the relationship between sleepiness and driving by recordings EEG during a driving simulation. EEG recordings allowed the authors to consider alpha and/or theta power as indices of sleepiness.

Campagne et al. [32] compared older adults (60–70 years) with two other age groups (20–30 years and 40–50 years). One group was required to drive on a lighted motorway, while the other group drove on a nonlighted motorway condition. EEG was acquired at baseline periods before the driving test and during the monotonous and pro-longed night-driving simulation. No difference between the two lighting conditions and among the three age groups was found concerning the EEG patterns. Driving errors did not vary between the two lighting conditions. However, driving errors such as “running-off the road accidents” were more frequent in young subjects. Differently, speed variability was higher in older drivers, consistently with the observations of Song et al. [40]. Only young adults showed in both conditions a positive correlation between alpha power (high alpha power = low vigilance) and driving errors (i.e., running-off the road episodes on the left-hand side). Separate analyses on the two lighting conditions revealed a positive correlation between sleepiness and driving errors in the younger group during the lighted condition. For the older drivers, no correlation was found between any type of running-off the road errors and vigilance level assessed through the alpha power, whatever the lighted conditions. Differently, a positive correlation between the theta power and driving errors was found for older adults. Moreover, the theta power—representing a high level of sleepiness—was correlated to the speed variability in this group during a lighted condition. In the older group, excessive, low, and overall speed values were associated with the total number of running-off the road accidents.

Moreover, the analysis of the time course of the EEG power in the alpha and theta bands showed a significant increase in both indices during the prolonged driving task at night. Driving errors increased progressively as the number of laps increased.

A physiological assessment through EEG during the driving simulation was carried out also by Lowden et al. [40]. Ten young drivers (18–24 years) were compared with ten older drivers (aged 55–64 years). In this study, each subject participated in two 45-min driving simulations: (a) morning driving and (b) evening driving. The driving period was divided into 5-min bins (9 intervals), and the factor "time" was included in the analysis. Results showed that EEG power activity increased across the nine 5-min bins. In particular, alpha and sigma power (8–14 Hz) showed an increase. A main effect of age was observed for higher frequency band (12–32 Hz) that being increased during both conditions in older drivers. Age differences became bigger at the end of the night. Indeed, older drivers showed increased power in the frequency 10–16 Hz. Moreover, the sigma 1 band (12–14 Hz) increased across the time and was higher in older adults.

Further, after driving, increased salivary cortisol in older adults was found compared with the younger group. Subjective sleepiness evaluated by KSS was higher during the night driving in both groups. However, sleepiness appeared to be more pronounced in young subjects than older drivers during the night and at the end of the driving simulation.

The last EEG study by Filtness et al. [37] evaluated sleepiness at the wheel only in the early morning, considering two different situations: (a) after a regular night; and (b) after a sleep restriction. Twenty young subjects were compared with 19 older drivers. EEG was recorded during the driving task, and subjective sleepiness was assessed at regular intervals. After normal sleep, no difference between groups was found. Following sleep restriction, both groups had more driving accidents. A time effect was also observed: both age groups increased the number of incidents during the task. Moreover, in this condition, the younger group showed significantly more sleepiness-related incidents during driving simulation. Partly according to Campagne et al. [39], alpha and theta (4–11 Hz) EEG power was higher in younger drivers than older drivers. Consistently, subjective sleepiness (KSS) positively correlated with EEG measures after sleep restriction in both groups.

3. Summary

Overall, most of these findings indicate that older drivers are less vulnerable to sleep loss and sleepiness-related driving impairments than young adults [39][40][37][32][41]. These discrepancies in sleepiness vulnerability between age groups may be due to differences in subjects' lifestyles. For instance, young participants could have poor sleep habits and a sort of "chronic sleep deprivation", as hypothesized by previous literature [42][43], and observed in studies on the consequences of COVID-19 on sleep-wake rhythm [44][45][46].

It is worth noting that this conclusion should be taken with caution since some studies revealed that older adults might underestimate their level of sleepiness in the assessments by self-report instruments [47][48], and the time of the day in which the studies have been performed could have affected the results [37][34].

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