

Literature Review about the Effects of Integrated and Nomadic Navigation Systems on Road Traffic Safety

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A question to my peer reviewer. May I ask you to take a look at the overall coherence of my literature review? Does it give you a coherent picture of what's going on in this field of study? In what sense yes or no? I feel personally that this is one of my most important improvements to make. Thanks, all the best.

1 LITERATURE REVIEW

This section aims to provide an overview of previous studies on navigation-assisted driving and its impact on road safety, including the types of distractions and interface design, as well as the indicators of road safety used in previous studies.

Grahn and Kujala conducted a study in 2020 that aimed to compare the degree of visual distraction caused by smartphone-based applications to that caused by a specialized application for cars (Carrio). The study involved two different experiments (n=97) conducted in a driving simulator. Visual distraction was measured in terms of distance driven with occluded vision (occlusion distance). According to their findings, the specialized application caused less visual distraction due to its specialized user interface design, the division of tasks into subtasks, and, to a lesser extent, the size of the screen [1]. The same study found that task structure, specifically how tasks are divided into subtasks, is important. People tend to switch tasks at subtask boundaries, such as between words, and this has implications for reducing distraction in car information systems [1].

In an analysis of distraction by car infotainment systems, a team from University of Utah tested differences in cognitive load between various functions and interface components for car infotainment systems (IVIS) [2]. In this naturalistic study (N=120), distraction was measured using the ISO standardized Detection Response Task (DRT) measure, and by a set of subjective measures, gained by a questionnaire after each driving session. The research found significant differences between various applications (like navigation, entertainment, messaging or dialing) and various components of user interfaces with respect to driving performance. Simulation studies such as Grahn and Kujala [1] or Jun Ma [3] are the most frequently used methodology in similar studies, followed by naturalistic studies as the second most common approach [4].

2.1 Types of distractions

Use of navigation systems may introduce various types of distractions, classifiable as cognitive, visual, manual, and auditory [3][5], which can impact driving performance and road safety.

Numerous of the reviewed articles focus on visual distraction, which tends to be measured in terms of glances/glance duration/glance behavior, or similarly fixation count or duration. Visual distraction seems to be highly represented in previous studies into distracted driving. It is also a core concept in the US National Highway Traffic Safety Administration 2013 driver distraction guidelines for in-vehicle electronic devices [6] which as reported by Kujala and Salvucci suggests three main guidelines to minimize: (1) individual glance duration, (2) mean glance duration, (3) total glance time [7]. Additionally, it should be noted that the same study notes that glancing and visual distraction are not necessarily equivalent.

While cognitive distraction by itself is difficult to measure, the adverse effect it has on driving performance has been observed in lab studies [8]. A benchmark of four measures of driver workload by McDonnell et al. observed Task Interaction Time to be most sensitive to work load differences between 40 tested cars, followed by DRT Miss Rate, NASA-TLX and DRT Reaction Time. Furthermore: the latter two measures were found to require a sample size larger than the sample size in their study (n=173) to have sufficient power [8].

While voice control allows the driver to keep the eyes on the road, a trade off is that voice control tends to cause higher cognitive load compared to manual interaction (excluding touch screen). Steering wheel button control in combination with voice control have been found a beneficial combination for the more basic tasks [3]. Mitigating high cognitive load by full text visual feedback in turn causes high visual load and time pressure, which in turn may be mitigated by visual feedback in the form of keywords and icons [5].

2.2 Relation between interface design and driving performance

Comprehensive literature review by Oviedo-Trespalacios, et al resulted in an extensive list of secondary in-vehicle tasks such as conversing, reaching, answering calls, dialling, browsing, reading, texting and typing [4]. These IVIS-related tasks mentioned in this study can be considered unhelpful distractions, together with adjusting the radio, entertainment systems, dealing with irrelevant (navigation) data, and specifically to nomadic systems: popups and notifications by for instance social media or disruptions and interruptions of the navigation application.

User interface design for cars has been mentioned as 'a community' [5], pointing at the fact that it has a certain maturity as a field of study. This literature review has observed improvement of car safety to be a key driver of this field. Car navigation systems for

consumers have been around since Mazda introduced them in 1990, at the time as a system integrated with the car [9]. Since, the market has additionally seen dedicated navigation devices (like a Garmin or TomTom device), smartphone navigation apps (like Google Maps), and more recently, the linking of smartphone navigation apps to the car IVIS, for instance by cable or Bluetooth. At least iOS (Apple CarPlay) and Android (Android Auto) currently support such features. The latter mentioned feature may be considered a sort of hybrid between nomadic navigation and navigation via the car integrated IVIS. It has the advantage of staying up to date automatically, contrary to other dedicated navigation devices or integrated IVIS navigation applications, which must be updated manually. Given that not everyone updates their navigation system [9], and given that an updated navigation system improves the user experience and potentially even safety, the mentioned hybrid system potentially has an advantage.

Interaction modalities: Haptic feedback can help alleviate visual distraction and allow the driver to focus on the road [10]. Audio feedback, such as a "read aloud" feature, can also be helpful, although it may not be as effective in some situations and can still cause cognitive distraction [1]. Different input modalities for certain tasks, or different mixes of modalities are likely to have an effect on cognitive, visual or manual distraction. A 2022 study by Jun Ma et al suggests a well designed touch screen may be more suitable for certain complex secondary tasks, compared to knobs and buttons, despite the fact that knobs and buttons are by themselves more simple to operate [3].

Multiple studies have identified navigation destination entry as highly demanding [10][11], and in at least two instances it was even identified by direct experiment as the most demanding secondary task [2][3] among other common tasks such as text messaging, dialing and radio volume adjustment.

2.3 Driving performance indicators

Besides in-vehicle tasks, Oviedo-Trespalcios created an inventory of "Human Machine Systems" (HMS) performance metrics: headway, lateral position (lane position), speed, crashes, and workload [4]. The mentioned metrics may be considered synonymous, or closely related to driver performance indicators.

Analysis reveals that the design of the IVIS interface affects driving speed. Engaging in activities such as conversing, dialing, or texting while driving leads to a decrease in driving speed and an increase in headways [4]. This is a well-known effect and named by Young and Regan as "compensatory or adaptive behavior" [11]. Lane position has been found to be impacted by visual and manual load. Also voice control that generates cognitive load has been found to affect departures from the lane center (more so than on speed control). Still voice control seems to distract less than operating a touch screen. [3]. Furthermore, it has been shown that voice control with full text visualization leads to higher headway variability, attributed to higher total glance durations [5].

The positive association between secondary tasks while driving and decreased driving performance seems to be moderated by environmental factors that impact the complexity of driving tasks [12]. Also minding the interdependencies of distraction variables, Kandemir, et al. propose the existence of "toxic" task combinations

in which certain tasks, while not overly burdensome on their own, may surpass a certain threshold when performed in conjunction with more complex tasks, such as dialing while simultaneously braking at a red light [13]. In a similar sense, Oviedo-Trespalcios have approached what they called "Mobile Phone Distracted Driving" as a human-machine system. They have focused their observations not just on distractions by certain tasks, but also by conflicts that occur between combinations of tasks [14].

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