Automated Vehicles as Assistive Technologies: An outline of the promises and challenges of using automated vehicles to extend the safe driving of older adults with dementia

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Automated vehicles hold a great promise in sustaining the safe driving mobility of older adults whose driving has been compromised due to age-related impairments. Such impairments are also projected to be a leading cause of road crashes by 2025. Cognitive impairments, such as dementia, pose a distinctive challenge due to its progressive nature and the individuals' potential lack of insight about their driving deficits. It is thought that automated vehicles can be deployed to assist older adults with dementia to extend their safe driving period, thereby avoiding the adverse consequences of driving cessation and enhancing road-safety. However, current automated vehicle designs do not consider the unique abilities of this cohort, which could lead to a mismatch between the ultimate designs of automated vehicles and the capabilities of these users. Consequentially, this could result in the same restrictions they face with non-automated driving or worse, leading to negative road incidents. With an ultimate objective of designing automated vehicles compatible with the abilities of persons with dementia, this paper presents a view of such vehicles as assistive technologies and outlines a non-comprehensive list of factors that should be carefully considered as a part of this implementation. Speculations regarding the usefulness of this technology as a method of avoiding or delaying the adverse consequences of driving cessation in persons with dementia will only be realized if their unique needs are addressed.

1 BACKGROUND

Revoking an older adult's drivers' license can result in significant adverse psychological and physical health consequences. Independent driving is associated with older adults' sense of identity and autonomy, and it has been dubbed as an "asphalt identikit" that allows them to maintain a non-age-related identity (Eisenhandler, 1990). During the same decade when the theory of "asphalt identikit" was formulated, automated vehicle technologies were being pursued by major companies and research organizations that would ultimately change the nature of driving and authorizations to drive. Since then, both the theory and technology have come a long way, with the recent literature demonstrating that each of the two research areas of older adults' driving cessation and automated vehicle design are much more complex than initially thought (Bagloee, Tavana, Asadi, Oliver, 2016; Curl, Stowe, Cooney, Proulx, 2014; Plastow, 2017) – a potential reason why the integration of the two, to the best of authors' knowledge, has rarely been pursued. Importantly, if designed appropriately, automated vehicles hold great promise to extend the safe driving of older adults whose driving abilities have been compromised by age-related impairments.

Automated vehicles have the potential to, not only provide significant benefits to older adults in sustaining their driving mobility, but also to increase road safety for everyone. This is because by 2025, more than 40% of all fatal crashes are projected to be due to age-related frailties, with cognitive impairments among the major contributing factors (Staplin, Lococo, TransAnalytics, 2003). Compared to other medical reasons for older adults' driving cessation, cognitive impairments, and more specifically dementia, pose a unique challenge, partly due to dementia's progressive nature, heterogeneity in the types of deficits presented in each individual, and the individuals' potential lack of insight about their impairments.

1.1 Problem Identification

This article aims to provide an outline of the areas of research requiring further investigation to ultimately ensure that the benefits of automated vehicles can be reaped by those with cognitive impairments, who may have the most to gain from these technologies in terms of sustaining their driving mobility. To this end, it is useful to first view automated vehicles as assistive technologies.

2 VIEWING AUTOMATED VEHICLES AS ASSISTIVE TECHNOLOGIES

In an attempt to view automated vehicles as assistive interventions, the terminologies used in this paper will conform to the standard language and framework of the World Health Organization's International Classification of Functioning, Disability, and Health (ICF; WHO, 2002). In this framework, disability and functioning are viewed as outcomes of interactions between a health condition (dementia) and environmental and personal contextual factors that can lead to limitations in executing activities and/or restrictions in participating in life situations. Figure 1 provides a simplified diagram of this biopsychological model of disability in a context of driving and dementia. The contextual factors in this diagram could present opportunities to better align the context of driving, including the design of the automated system, with the individuals' abilities such that it maximizes their functioning and leads to minimal activity limitation and/or participatory restrictions.

2.1 Capacity qualifiers versus performance qualifiers of driving activity

In the context of driving and dementia, we are concerned with the limitations that dementia can cause in the activity of driving. However, in an automated vehicle, depending on the design, the tasks involved in the activity of driving are altered compared to non-automated driving, but not necessarily reduced (Dekker Woods, 2002). For instance, a Conditionally Automated Vehicles (SAE Level 3) introduces the task of take-overs to driver's responsibilities, thereby altering the responsibilities of the driver compared to non-automated driving. This divergence of individuals' responsibilities with and without an assistive technology is conceptually consistent with the difference between "capacity" versus "performance" qualifiers in the ICF model.

The capacity qualifier describes the individual's ability to perform driving tasks without any assistive technologies. In the context of driving, capacity qualifier can describe the ability of the individual to perform non-automated driving tasks, which include low level operational tasks (steering and speed control), mid-level tactical tasks (object and event detection and vehicle maneuvering), and higher level strategic tasks (navigation), all of which require drivers' constant monitoring (Michon, 1985). To qualify the driving capacity of individuals with dementia, de Raedt, et al. (2000) and Grace, et al. (2005) tested individuals' abilities on these three levels and found that while individuals with dementia made errors on all three levels, low tactical performance were associated with higher accident rates among the three. In addition, depending on the individual's level of insight about their driving deficits, individuals may exhibit compensatory behavior on all levels especially on an operational level by driving more slowly or allowing for a higher headway gap.

In contract to capacity qualifiers that describe individual's abilities without assistive technologies, performance qualifier describes the individual's ability to perform tasks in their current environment, which may include assistive vehicle technologies, semi-automated vehicles, or in future, highly automated vehicles, which could, depending on the design of the vehicle, encompass a different selection of driving activities as outlined in Figure 2. As such, the objective of automated vehicle design for older adults living with dementia may involve (1) allocating them a selection of activities that they can effectively perform, and/or (2) maximizing their functioning in those activities by supporting

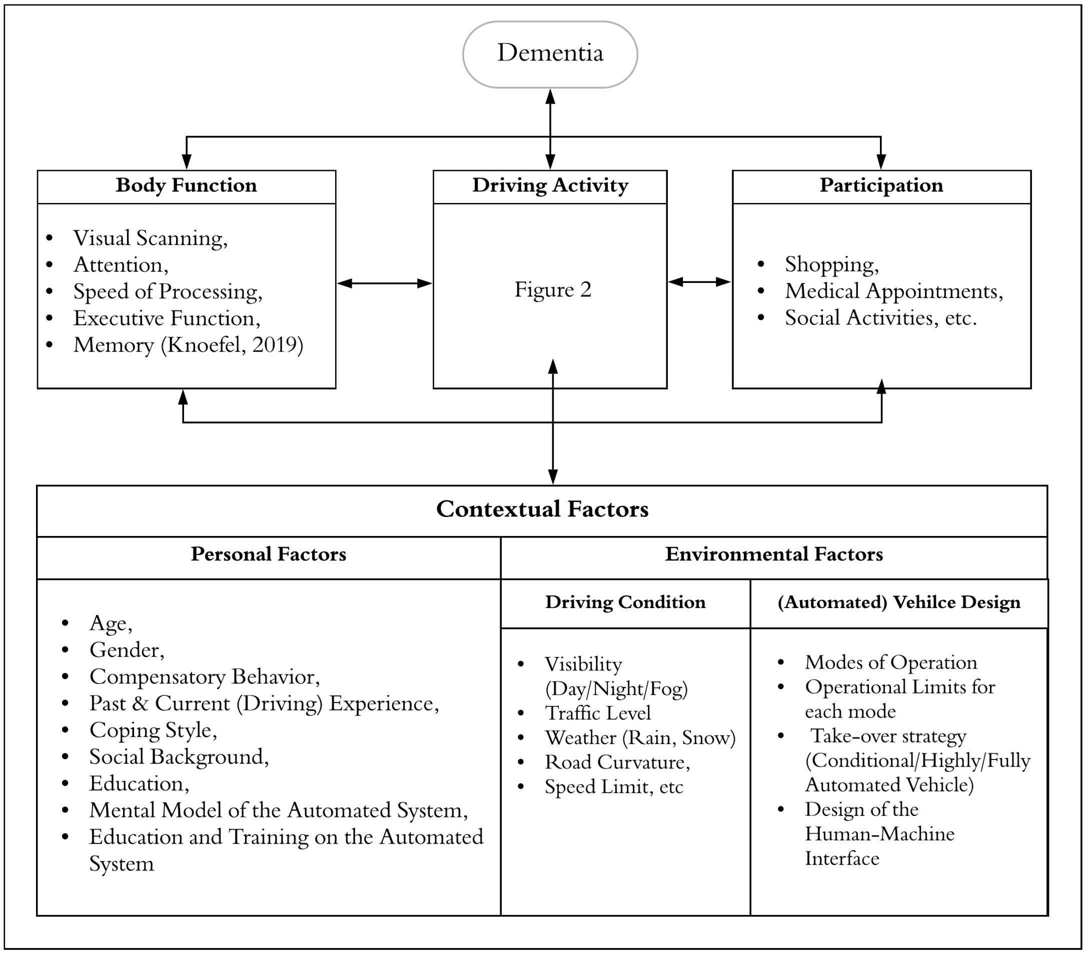

Fig. 1. The diagram adapted from ICF model of disability (WHO, 2002) to frame the interaction of dementia as a health condition with potential limitations in driving activities and restricted participation.

them with suitable vehicle design. As an hypothetical outcome, this could for instance translate into blocking a certain level of automation in the vehicle that requires the driver to take-over the driving control, or restricting the geographical operational limits of the vehicle such that it only travels to certain destinations.

3 ANTICIPATED CHALLENGES

3.1 Matching the Automated Vehicles' Design to Individuals Capacity

3.1.1 The progressive nature of declines in older adults living with dementia. The first anticipated challenge towards achieving the two objectives described in 2.1 is that, due to the neurodegenerative nature of dementia, individual's performance can deteriorate over time and the rate of deterioration can differ from one individual to another. Therefore,

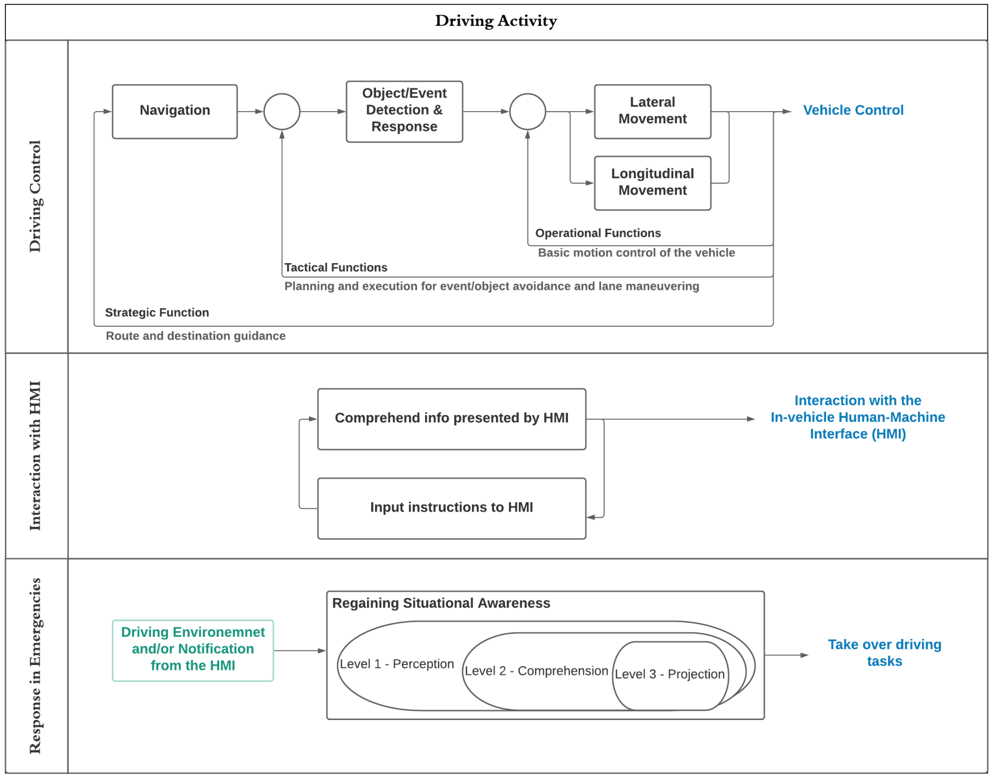

Fig. 2. An overview of the tasks that the driving activity could entail depending on the design of the (automated) vehicle. Non-automated driving task are based on Michon's (1985) levels and adapted from SAE (2018) and Merat (2019). The take-over stages are adapted from Ma Kaber (2005).

the objectives described above are a "moving target" that can change over time with different rates of change for each individual, which has the following implications, (1) if the automated vehicle requires the individual to perform a driving activity, regular driving assessments will be required from these individuals to assess their capacity to perform this driving activity. (2) The design of the automated vehicles may need to further incorporate driving performance monitoring systems and strategies for when the individuals' performance in the vehicle is deemed unsafe.

3.1.2 The heterogeneity of the nature of declines in older adults living with dementia. Another complicating factor is that the types of declines in individuals living with dementia (Body Function in Fig 1) can differ from one person to another and influence their driving capacity at different levels (CMA, 2015). Accordingly, performance with an automated vehicle of the same design can differ from one person to another, which highlights the need for accommodating personalization of the automated vehicle design.

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