Designing the Communication with Automated Vehicles: The Case of Elderly Pedestrians

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To communicate perception of and intent to other road users, implicit and explicit forms of communication for automated vehicles (AVs) are currently under research and development. Despite being a relevant group for road safety, the requirements of elderly pedestrians are not sufficiently reflected in current communication concepts. Age-related impairments of sensory, cognitive and motor abilities of elderly pedestrians are presented and their relevance for design criteria of implicit and explicit forms of communication for AVs derived. The specification of design criteria presented in this paper allows further research to examine the design of implicit and explicit communication for AVs with elderly pedestrians.

Additional Key Words and Phrases: elderly pedestrians, automated vehicles, human-machine interaction, communication, age-related impairments

1 BACKGROUND

As the proportion of elderly people (age 65 and older) in western countries is increasing [38], there is a growing interest regarding the mobility needs of this demographic group [57]. Walking as a pedestrian is one common mode of transportation for elderly people [33]. Among all road users, pedestrians represent an especially vulnerable group in road traffic [37]. While elderly people represent 20% of the EU population they account for 47% of all pedestrians' deaths in the EU [3], making them a critical age group regarding road safety. Aging brings greater difficulties in crossing the road especially in complex traffic scenarios such as two-way roads [17, 19, 40]. Difficulties in road-crossing behavior of the elderly have been attributed to age-related declines in sensory, cognitive and/or motor abilities [16, 41].

Today, road crossings by pedestrians can be accompanied by the interaction with human drivers, which is characterized by an exchange of implicit (e.g. deceleration, gait) and explicit (e.g. hand gestures) signals [14, 55]. In doing so road users communicate perception of and intention to other road users in their environment [35]. With automated vehicles (AVs) in the urban transportation system new challenges arise [5], one of them being the communication of AVs with other road users [42, 55]. While research has focused on designing implicit and explicit forms of communication for AVs [e.g. 1, 48], elderly people have only seldom been the user group of design and evaluation [e.g. 26, 34, 39, 44].

This paper highlights the gap between current design concepts of implicit and explicit communication for AVs and the requirements of elderly pedestrians. Therefore, age-related impairments of elderly pedestrians are described (section 2) and their relevance for current developments in implicit and explicit forms of communication for AVs derived (section 3). This (brief) review shall inform further research examining the design of communication between elderly people and AVs by deriving research gaps in literature (section 4).

2 AGE-RELATED IMPAIREMENTS OF ELDERLY PEDESTRIANS

To ensure safe road-crossing decisions, pedestrians must "share their attention, select the most appropriate information and inhibit the information that is non relevant" [16, p. 136], followed by the execution of an action to cross the road.

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Thus, participation as a pedestrian in road traffic requires the integration of sensory, cognitive and motor abilities [16, 60].

2.1 Sensory abilities

The visual and auditory perception are of great relevance in road-crossing decisions of pedestrians [43]. Known age-related deteriorations of visual perception are the decline of central and dynamic visual acuity [8, 24] with the latter being of particular relevance for motion perception [54]. Moreover, the aging eyes' impaired accommodation hinders their ability to adapt between focusing near and far [8]. While contrast sensitivity as well as color discrimination are reduced, glare sensitivity is increased [8, 24]. Since the interaction of the foveal and peripheral visual field forms the basis for visual orientation, age-related narrowing of the "Useful Field of View" must be considered as well [52]. With regard to auditory perception, the elderly person's ability to perceive and locate acoustic signals and to filter out unwanted sounds is hampered [18, 51].

Age-related declines in sensory abilities have been shown to impact road-crossing decisions of pedestrians [15, 16]. The visual perception is necessary to perceive objects at a distance, to recognize signs, signals and other road users and to correctly estimate speeds. Because of their limited sensory abilities, elderly people have difficulties in estimating the time-of-arrival (TTA) of approaching objects and cars [4, 50], potentially leading to dangerous crossing decisions.

2.2 Cognitive abilities

Cognitive abilities refer to skills such as attention, information processing and the ability to reflect and represent memory content [47]. Elderly people need more time to assess a stimulus' contextual relevance and are easier and longer distracted by irrelevant stimuli due to impaired inhibition [22, 25]. Having difficulty in flexibly distributing attention between two tasks, maintaining a prioritized focus and switching between them, situations requiring divided attention pose problems for the elderly [23, 53]. Combined with the age-related reduction of a person's limited working memory [7] and the reduced speed of information processing [49], the search for target stimuli in complex environments under time constraints is impeded [59].

Due to age-related declines in cognitive abilities, elderly pedestrians are more likely to have difficulties in the decision making process when crossing a road, especially under time pressure [60]. Related gap-selection issues of elderly pedestrians [32, 41] are also attributed to decreasing cognitive abilities that pedestrians need to focus on relevant information and to make timely, correct decisions [16].

2.3 Motor abilities

Changes in the bone, joint, ligament and muscle apparatus have effects on mobility, speed of movement, balance, coordination and strength [10]. A decrease of muscle strength of up to 30-40% over the lifespan [46] and a decrease in mobility of about 3-5% per decade [56] reduce the elderly person's ability, power, controllability and precision of movement execution [46]. With increasing age, sensomotoric tasks like everyday movement patterns require more conscious control and cognitive resources, limiting the capacity to perform multiple activities simultaneously [31].

Elderly pedestrians display slower walking speeds while crossing a road [32, 40] whereby walking time is a relevant factor to predict the safety of pedestrian crossing behavior [27]. Difficulties to adapt their walking speed to prevailing traffic conditions further explain gap-selection problems of the elderly [15, 16].

3 DESIGN CONSIDERATIONS FOR THE COMMUNICATION BETWEEN AUTOMATED VEHICLES AND ELDERLY PEDESTRIANS

While research on age-related impairments and their influence on the behavior of elderly pedestrians exists, little research has been done regarding the communication and interaction between AVs and elderly pedestrians. Nevertheless, initial studies have shown that light signals on AVs (light bar on the rooftop) were assessed more positively by elderly pedestrians compared to younger pedestrians (aged 21-30 years) in terms of usefulness and satisfaction [26]. Another study identified the preference of elderly people for multimodal designs (combination of visual and auditory signals) of external Human-Machine Interfaces (eHMIs, e.g. light signals or displays on AVs) but could not find any difference in reported user experience (using the UEQ [29]) between younger (20-30 years old) and elderly pedestrians [39]. Furthermore, a video analysis revealed differences in road user behavior of older people when interacting with an AV, with older pedestrians (aged 55 years and above) stopping more often to give priority to the AV [34]. This result was supported by a simulation experiment in which older pedestrians (aged 40-69 years) were more hesitant about interacting with an AV when crossing a road [44].

While these studies show that there are age-related differences both in subjective assessment as well as behavior when interacting with AVs, none of the above-mentioned research explicitly considered age-related impairments of pedestrians in the design of implicit and explicit forms of communication for AVs. Table 1 compiles age-related impairments and resulting difficulties of elderly pedestrians and matches them with the most relevant design criteria of current developments for the communication design of AVs. Research on older drivers served as a basis to assign design criteria to age-related impairments of pedestrians [e.g. 11]. Further, the relevance of age-related impairments, resulting difficulties of elderly pedestrians and significance of design criteria were discussed in two structured feedbacks during the preparation of this position paper.

Table 1. Age-related impairments of elderly pedestrians and their relevance for designing pedestrian-AV-communication

Age-related impairments	Difficulties of elderly pedestrians	Most relevant design criteria
Sensory abilities		
Central acuity	Object perception, sign and signal recognition	Modality, coding, position
Dynamic acuity	Motion perception, TTA and speed estimation	
Accommodation	Change of focus between near and far objects	
Contrast sensitivity	Distinguish between objects and backgrounds	
Color discrimination	Distinguish between colors of signals	
Glare sensitivity	Loss of central acuity in bright light	
Hearing	Hearing loss, locating of acoutic signals	
Cognitive abilities		
Inhibition	Suppression of irrelevant information	Content, coding, perspective, timing
Selective attention	Concentration on a certain stimuli in the environment	
Divided attention	Attend different stimuli at the same time	
Working memory	Amount of available cognitive resources to store information	
Speed of information processing	Making timely decisions	
Decision making under time pressure	Making correct decisions (e.g. gap-selection)	
Motor abilities		
Movement execution	Speed of walking and head rotation	Content, timing, position

Relevant design criteria determining the communication between AVs and pedestrians are the content road users are exchanging [6, 21] and the timing of the communication [1, 12], e.g. the starting point of deceleration to convey a signal [1]. Furthermore, explicit forms of communication (via eHMIs) include the criteria of modality [9], perspective (e.g. ego- vs. allocentric) [6], coding of information (e.g. form, size, color, frequency and amplitude) [2, 6, 13, 30, 58] and position on the vehicle [2, 20].

Because of declines in sensory abilities elderly pedestrians have difficulties to perceive objects at a distance and correctly estimate speeds [16, 41]. However, adaptation in speed is a main transmitter of implicit forms of communication of vehicles [1]. Having difficulties with this communication form, elderly pedestrians might benefit more from eHMIs (e.g. visual and/or auditory stimuli). But also in the design of explicit forms of communication of different modalities, coding and positioning of information transmission must be adapted to age-related impairments of sensory abilities (e.g. decline of central acuity).

Due to declines in cognitive abilities, elderly pedestrians have difficulties to focus on relevant information, to flexibly distribute their attention and to make timely, correct road-crossing decisions [16]. To enable elderly pedestrians to process the information conveyed correctly and in a timely manner, the information must be presented in an easily graspable form being the result of careful decisions in the relevant design criteria of content, coding and perspective. Another important design criteria to be considered here is the timing of communication [1, 12]. Elderly pedestrians could benefit of an early communication onset, relieving them from decision making under time pressure.

Declines in motor abilites of elderly pedestrians are related to difficulties of adapting a chosen road crossing strategy [32, 41]. In terms of content, AVs should therefore avoid communication that forces elderly pedestrians to (rapidly) adjust their current road crossing strategy. In addition, the immobility of the elderly people's neck must be considered when determining the information position. Finally, an AV needs to have a high contextual understanding of its environment in order to take the elderly pedestrians' lower walking speeds into account and to give them enough time to execute their preferred strategy.

4 CONCLUSION

Despite being a relevant group for pedestrian road safety, current developments of implicit and explicit forms of communication for AVs have neglected the requirements of elderly pedestrians. Age-related impairments contribute to difficulties of elderly pedestrians when crossing a road [16, 17] but this has not been cooperated yet in any communication designs for AVs. The specification of design criteria presented in this paper allows further research to examine the design of implicit and explicit communication for AVs with elderly pedestrians.

Elderly pedestrians seem to perceive AVs as useful [45] or even less risky than being around human-operated traffic [28]. In order to increase the chances of improving road safety of elderly pedestrians, the human-oriented design approach for the elderly pedestrian population should be enhanced and pursued. Further research could investigate compensation strategies for age-related impairments [41] and self-regulation behavior of elderly pedestrians [36] in their interaction with AVs.

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A VIDEO

A video presentation on this position paper is online at YouTube (see https://youtu.be/JlRGugx_q34) and can be downloaded in full resolution from this URL: https://hessenbox.tu-darmstadt.de/getlink/fiVPPgYoo1ePGVbYiayXpfnV/.