Automated Vehicles as a Possibility for Inclusion

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This paper outlines the flaws in the design process for developing vehicles and pinpoints how these flaws are linked with the limitations people with impairments face when trying to use modes of transportation. The characteristics of the main categories of impairments are listed in order for them to serve as a base for improving the design approach. The aim of this paper is to give ideas for further research regarding the HMI of AVs and highlight how the development of inclusive solutions for methods of communication between AVs and users can help the 'differently-abled' become independent and have the possibility to be involved in all social activities equally.

Additional Keywords and Phrases: disabilities, human-centric design, inclusive design, autonomous vehicles, HMI

1 INTRODUCTION

In product development, following the principles of 'universal design' [1] and 'inclusive design' are a responsibility of all sides included in the process - from research and planning, to organization, design, construction etc. This is how a product offers flexibility in use and is able to respond to the needs of everyone equally including persons with disabilities. The 'ITS Report' [2] mentions the fact that disability is a social phenomena that appears as a result of obstacles and limitations in the environment, meaning that it is a result of poor design of the environment in which specific individuals are not able to perform basic activities.

Regarding transportation, these design flaws result in exclusion of people with disabilities from many social processes. People with impairments leave their homes less frequently, are less likely to be employed, use each mode of transportation way less compared to people without impairments, and more than one third of the impaired population are not active drivers [3].

The pinpointed need to help the individuals with impairments become more involved in all social activities emerges from an analysis of multiple researches [4, 3, 2, 5, 6] regarding disabilities and transportation. The most common limitations include inability to drive, expensive modified vehicles, issues with moving through urban environments due to obstacles etc. These limiting factors result with serious issues such as limited possibilities for education, employment, use of medical services, social isolation, depression and mental disorders etc.

2 AUTOMOTIVE DESIGN AND INCLUSION

Modern technologies and novelties in automotive design offer the possibility to reduce or even eliminate these limitations and the effect they have on the everyday lives people with impairments.

Vehicle manufacturers offer possibilities for inclusiveness. They develop vehicle models and modifications taking into consideration the structural and functional anthropometric measurements of persons with disabilities including the mobility-aid devices they use [7, 8, 9, 10], and recommendations for space dimensions in order to accommodate persons with disabilities [11]. Vehicle modifications can be structural or non-structural [12], out of which structural modifications are more drastic and include adding components, changes in appearance, alternative ways of ingress/egress and modified ways of using driving commands. Institutions such as the 'NHTSA' [13] even offer consultations with rehabilitation specialists who analyze the capabilities of the individuals in order to recommend the most suitable vehicle modifications for safe and ergonomic use. Basic modifications of control devices that allow users to drive independently include: adaptations of the steering wheel, adaptations of the brakes, clutch, and gas pedals, adaptations of the shifter, adaptations of the driver seat, and adaptations in the vehicle exterior (wide entry, ramps) [14]. For example, the company 'BraunAbility' offers a variety of mobility solutions and handicap vans to be used by persons with mobility impairments as drivers or passengers [15]. For enabling persons with mobility impairments to drive, the basic rule is to redefine the commands as joysticks [16] so that all vehicle controls become hand controls. The model 'Kenguru' is a small electric vehicle featuring a back door, ramp and hand controls which allow it to be driven by wheelchair users [17]. Other models, like the 'MV-1' [18] are pre-built for wheelchair users, allowing easy accommodation of wheelchair users as passengers.

What all these models have in common as cons are that they are expensive [5] and they are all focused on users with mobility impairments, more specifically wheelchair users who only have lower limb impairment. There are no options for the persons with severe mobility impairments or visual and hearing impairments, as well as persons with psychological disabilities.

3 POSSIBILITIES THE AV TECHNOLOGY OFFERS

The development of autonomous vehicles can have a significant impact on reducing these cons and offer new possibilities for independent traveling for the disabled community including the elderly. This point was strongly emphasized by 'Google' in the first test drive of an autonomous vehicle in 2012 that featured a person with vision impairment in the driver seat [19]. A newer initiative is the 'Inclusive Mobility' from the 'Volkswagen group' launched in 2019 that has the primary goal to directly collaborate with individuals with impairments in the earlier stages of vehicle design [20]. Such methods of combining the autonomous technology with human-centric design and universal design principles will result with vehicles that are ergonomic and inclusive. Due to all these facts, the persons with disabilities show a strong interest to use autonomous vehicles and are most likely to be the early adopters of the self-driving cars due to all the benefits this technology can bring them.

Because the concept of fully autonomous vehicles is in development, there is space for upgrading and revising the design principles and improve the methodology for creating autonomous vehicle models. The design process needs to take into consideration the needs of persons with all different types of impairments, not only with mobility impairments. The main aspects that need to be addressed are: easy access, independent and easy ingress/egress, safe and comfortable accommodation inside the vehicle and easy and intuitive communication with the vehicle. As mentioned, physical modifications of vehicle models are not a

new concept, however, in order for an autonomous vehicle to be inclusive for people with vision, hearing, and psychological impairments it needs to offer novelties in the way it interacts with users. In this context, the most crucial aspect is the design of the HMI. With a properly designed HMI the AV can become fully inclusive. The development of technologies such as the use of smart surfaces [21], intelligent cockpit systems [22], personal assistants [23], head-up-displays [24], augmented reality [25] and so on, adds to the possibility for enabling independent use of the vehicle by persons with different types of impairments. The design of autonomous vehicles should find ways to include all these features, while following the principles of inclusion, from the earliest stages in the design process (from developing ideas, concepts and prototypes to final product).

One more aspect to be addressed beside the in-vehicle HMIs are external HMIs that also need to be developed taking into consideration the needs of vulnerable road users. Different types of communication are needed for increasing the safety of all participants in the traffic. External HMIs must use a combination of screens, projectors, light signalization, and auditory means of interaction in order to successfully deliver the message that the car is in autonomous mode, as well as inform about next planned actions, or even malfunctions. The proper combination of communication methods will mean that persons with disabilities won't miss out any important messages or warning signs that the vehicle is delivering.

4 UNDERSTANDING USER NEEDS

In order to deepen the knowledge regarding the needs for the HMI of people with impairments, the different types of disabilities need to be understood. In the table below (Table 1), based on literature review [2, 26, 27, 3, 5], the main types of impairments are listed and the disabilities related with vehicle use for each of the categories are stated in order to simplify the process of generating ideas regarding the special HMI requirements.

Table1: Types of impairments, disabilities and abilities of each category

Type of impairment		**Disabilities**
Mobility impairment	Upper limbs disability	Not able to use hand controls Not able to use safety restraint systems
	Lower limbs disability	Not able to board the vehicle independently without a moving-aid device Not able to use standard car seats Not able to use pedals
	Upper and lower limbs disability	Not able to use hand controls Not able to use pedals Not able to board the vehicle independently without a moving-aid device Not able to use standard car seats Not able to use safety wheelchair docking hardware nor safety restraint systems
	Changes in strength, sensation and other body functions	Not able to use hand controls Not able to use pedals Not able to use safety wheelchair docking hardware nor safety restraint systems

Visual impairment	Partial	Not able to board the vehicle independently without an aid device Not able to use the seat independently without an aid device Not able to use safety restraint systems independently Not able to use hand controls fully Not able to use pedals fully Not able to receive visual information
	Blind	
Hearing impairment	Partial	Not able to receive sound information fully without assistance
	Deaf	Not able to receive sound information
Speech impairment	Partial	Not able to use voice control
	Complete	
Psychological impairments	Cognitive impairments	Not able to give and receive information independently due to risk of misleading the system, misunderstanding and forgetting output messages
	Mental disorders	Not able to give and receive information independently and safely due to risk of unexpected behavior triggered by situations, colors, images, sounds etc.
	Learning difficulties	Not able to give and receive information independently and safely due to risk of wrong interpreting, forgetting, missing out, or misunderstanding words, numbers, messages, language, symbols etc.

5 FURTHER RESEARCH

Based on the analysis of abilities/disabilities and recommendations for designing inclusive autonomous vehicles [28, 2, 5], ideas need to be developed for features of the HMI. The points to be considered are:

- Methods for summoning
- Way-finding and navigation
- Accessibility
- Ingress/egress
- Accommodation
- Different means of communication (visual, auditory, tactile)
- Pairing with personal smart devices
- Safety features

Regarding external HMIs, ideas need to be generated regarding:

- Types of messages to be communicated
- Volume of sound messages
- Type of sound messages (they need to inform and alert, but not disturb)
- Used colors for projections, screens, light displays etc. (not create confusion)
- Size of used text or symbols
- Type of used symbols (universal and clear)
- 360° display

For generating the ideas, a holistic approach is needed and combining ergonomic and universal design principles, recommendations for inclusion, technical achievements in the automotive industry and, most importantly, potential user preferences. Steps for developing an inclusive HMI design approach should involve a thorough literature review and analysis of examples, conducting ethnographic researches to deepen the knowledge about the needs of persons with impairments, generating concepts, and evaluation of suggested options. The ethnographic research is the crucial aspect that can make the design approach human-centric and be the link between the end-users and the vehicle manufacturers. The outcome of this approach would be a successful design of HMIs for AVs which would allow equal involvement of all members of society in all social processes. This remains a topic for conducting further research and developing inclusive design solutions for the interaction of AVs and vulnerable road users.

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