

Autonomous Vehicle Design Anti-Patterns: Making Emerging Transportation Technologies Inaccessible by Design

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Fully autonomous or “self-driving” vehicles represent a potentially transformative shift in personal mobility. Given the emerging nature of self-driving vehicle technologies, however, guidance for accessible implementation is limited. It has been suggested that the result is that much of this emerging technology is being designed in a manner that will render it largely inaccessible for persons with disabilities. Borrowing from object-oriented programming we identify common barriers to accessibility which we argue are de facto anti-patterns in the design of accessible self-driving vehicle technology. Drawing from the literature and our own studies we describe design commonalities (anti-patterns) which we argue may pose problems for persons with disabilities. We believe that this work may provide direction for designers regarding how to better support the needs of persons with a range of disabilities in the self-driving vehicle context.

INTRODUCTION

Autonomous vehicles (AVs) have been described as one of the most significant advances in personal mobility of the past century. The most advanced of this technology, fully autonomous or “self-driving” vehicles (SAE International, 2018), have been described as potentially improving traffic safety considerably by minimizing the role of arguably error-prone human beings in the driving process (Crew, 2015). The resulting technology will see the human occupant act less as an active driver tasked with manipulating safety critical controls (e.g. steering, braking, acceleration, etc.) while acting more as an operator working in conjunction with an artificial intelligence (AI). Despite the reimagined role of the human occupant there are emerging concerns about the human-machine interaction with this technology that has, as of yet, not become commercially available. Of specific focus are issues of the technology’s accessibility (Brinkley, Daily, & Gilbert, 2018; Brinkley et al., 2020; Brinkley, Posadas, Woodward, & Gilbert, 2017; Huff, DellaMaria, Posadas, & Brinkley, 2019; National Federation of the Blind, n.d., 2016). There are concerns specifically that the design of this technology is focused on the needs of the driver of the present, who in all cases is sighted and has sufficient physical and cognitive abilities to manipulate a vehicle’s manual controls. This stands in contrast to design which ideally would include the needs of the operator of the future who may be blind or have other physical or cognitive impairments which would typically render it impossible to operate a conventional motor vehicle.

We argue that within the current paradigm, absent concrete guidance that dictates what constitutes accessibility within the self-driving vehicle context (Brinkley, Daily, & Gilbert, 2019b), this emerging technology is largely being designed in a common manner which supports the proliferation of inaccessibility. Borrowing the language of object-oriented programming, we argue that these commonalities essentially amount to anti-patterns (Brown, Malveau, McCormick, & Mowbray, 1998; Wolfgang, 1994); common approaches to design that are ineffective and counterproductive. Within this work, in an effort to contribute

to the growing body of literature on AV design, we describe design strategies common in the AV design domain which we argue may serve as de facto barriers to accessibility. We describe our studies and the studies of others which have explored accessibility in the AV context and describe these anti-patterns in concrete terms. We argue that this work contributes to the understanding of what constitutes accessible design for persons with disabilities and older adults in their use of autonomous vehicles and may further support the wider use of anti-patterns as a theoretical lens to analyze design.

REVIEW

Design Patterns in Interaction Design

The concept of design patterns originated from architect Christopher Alexander in the 1970s when he introduced a collection of architectural design patterns for making future buildings and urban environments (Alexander, 1979). In his work, he defines a series of interconnected patterns and how they provide user-friendly solutions to recurring problems in architecture. Since that time, the idea of design patterns surfaced in other fields, such as software engineering, where researchers have developed their own collection of patterns for software design (Gamma, Vlissides, Helm, & Johnson, 1995).

Design patterns made their way into the human computer interaction (HCI) community in the late 1990s with the first collections of patterns appearing at the pattern languages of programming (PLoP) conference (Bayle et al., 1998). Since then, a number of works further launched interest in design patterns and pattern languages (Borchers, 2000; Mahemoff & Johnston, 1998a, 1998b; van Welie & van der Veer, 2003). A number of interaction design patterns have been published in books, including the triple pattern languages works of Borchers (2008), van Duyne, Landay, and Hong (2006) *Design of Sites*, Graham’s pattern languages for Web usability (I. Graham, 2002) and Tidwell’s book on user interface design patterns (Tidwell, 2020).

Within the HCI and software engineering communities, a pattern is defined as a structured description of an invariant so-

lution to a recurrent problem in context (Dearden & Finlay, 2006). Dearden and Finlay distinguishes patterns for interaction design and those for software design as interaction design patterns define solutions in terms of perceived interaction behavior of an interface (Dearden & Finlay, 2006). As Pauwels, Hübscher, Bargas-Avila, and Opwis (2010) explain, interaction design patterns are to be written for interdisciplinary use, given that interface design involves people from various professions such as designers, developers, researchers, and users. Bayle et al. (1998), to distinguish design patterns in HCI from software engineering, exclaims that patterns support a “lingua franca”, meaning they should support discussions with non-specialists in the field and be accessible and understandable by the end-users.

Tidwell, who champions design patterns, makes the case that designers should learn from others and in essence, “do what other people do” (Tidwell, 1999). It is this exact ethos, however, that has seen the proliferation of design that is effectively inaccessible for persons with disabilities in the autonomous vehicle context. Vehicles are being designed in a manner that is overtly similar and largely embeds inaccessibility which is then proliferated as other manufacturers borrow from the design. Within this paper we call out this commonality in design and describe these similar characteristics as anti-patterns that support inaccessibility.

AUTONOMOUS VEHICLE DESIGN ANTI-PATTERNS

We describe five commonalities in autonomous vehicle design which we argue have emerged as common solutions in the autonomous vehicle context. Given that these solutions may pose problems for persons with disabilities and older adults we argue that the proliferation of these design approaches amount to de facto anti-patterns in autonomous vehicle design. We describe five anti-patterns and reference related research where each is discussed.

Touchscreen-Centric Environments

Touchscreens (as in Figure 4) have become a common feature in the newest vehicles on the market. These screens allow for a multitude of functions to be accessed without the need for several buttons or other control mechanisms. (Pitts, Skrypchuk, Attridge, & Williams, 2014). Moreover, these displays can be used for a multitude of tasks based on the context of use, and their ease-of-use has been noted for both advanced and novice users (Ahmad et al., 2015). However, creating in-vehicle environments that are touchscreen-centric is ineffective for users with visual impairments given that these users may have limited usable vision, no usable vision or a limited visual field.

Brinkley et al. (2017), in a study investigating the opinions and preferences of blind or visually impaired persons about self-driving vehicles, found that many of the participants did not feel comfortable using a touchscreen interface to interact with the vehicle. The majority of participants anticipated their primary means of interaction with the vehicle would involve some form of speech input.

I hope it's so that you can just get in the car and say, "I want to go to "such and such church" and

it'll take you there. And I hope I can get in and say, "I want to go home", when it's over. (P11: Well) I hope they can simplify it somewhat. (P12)



Figure 1. In-vehicle touchscreen display (Brady, 2006)

Other participants expressed a preference to use their smartphones to interact and operate the self-driving vehicle, given that smartphones are already equipped with accessibility features they are familiar with:

I think that would probably be a good idea 'cause a phone is something I can, like, hold up closer to me so I can see it easier. And also, it will read it back to me, like, that's already accessible in that way versus like having to look at something else. And I'd also say to make like buttons or different things maybe more distinguishable, so you know which one is which. (P23)

It is worth noting that some participants did prefer to have the touchscreen interface as a backup means if their primary option was unavailable or inoperable. While the use of touchscreen displays should be an available feature for human-vehicle interaction with autonomous vehicles, it is critical to consider multiple alternative interaction methods for people with visual disabilities to enhance the user experience of operating such a vehicle (Brinkley, Daily, & Gilbert, 2019a; Brinkley, Posadas, Sherman, Daily, & Gilbert, 2019).

Visual Indicators for Situational Awareness

Today's vehicles use icons displayed to the driver as an indicator for any event that may be happening. Examples of this include low fuel, low tire pressure, and a loss of traction. These icons may be displayed on the vehicle's dashboard, a head up display (HUD), or a touchscreen interface (see Figure 2 for an example). The icons are vital because they inform the driver of the current situational status of the vehicle.

These indicators are insufficient for a visually impaired operator because they rely on the driver's vision. The lack of situational awareness may deter blind or visually impaired consumers from accepting and adopting AVs. Persons with visual disabilities would benefit greatly from a feature that would provide real time information given their current positioning. Participants from Brinkley et al. (2017)'s study confirm this assertion:

I think it would make the person sitting in the car feel a little bit more at ease. You know, that you know, since you can't see where you're going or where you're at, that it would tell you like, "Well, you know, we are like half a mile away from your destination." (P2)

A potential alternative is the use of auditory icons, which produces a sound representational of the event it is tied to. Prior research has studied the effectiveness of auditory icons in the automotive context such as vehicle emergency warnings (R. Graham, 1999; McKeown, 2005).

In incorporating auditory icons, it is important for the choice of sound to have a close, direct relation to the event to which it is tied (Keller & Stevens, 2004).

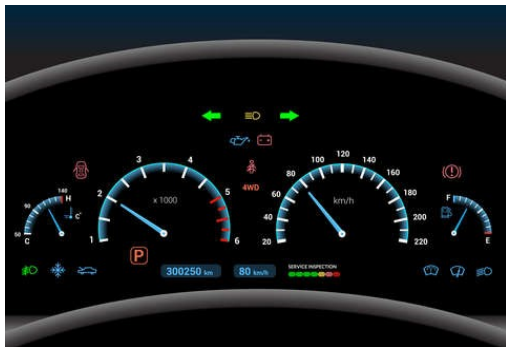


Figure 2. Vehicle instrument cluster (Miller, 2015)

Reliance on Visual Senses for Location Verification

The rise in the implementation of touchscreens in vehicles has allowed GPS navigation to become a built-in feature that does not require an external device (see Figure 3). Although some navigation systems have a voice interface to communicate directions to the driver, it is still the user's responsibility to visually check their surroundings and ensure that the navigation system takes them to the correct destination. It is also necessary for the drivers to be aware of their surroundings throughout the journey.

For visually impaired operators, this would prove be significantly challenging. A feature that would notify the operator of their current location and verify that they have reached their destination would dramatically improve the safety of people with visual disabilities, as indicated in Brinkley et al. (2017)'s study:

I think my operating system should take care of it. You know? It's like she'd...she'd take care of everything. So, I think the operating system should say, "Don't get out of the car. You're in the wrong...you're in a field." (P32)

Fixed Seating

Depending on the level of autonomy, AVs may not require any vehicle occupant as a driver. Similar to other occupants, the driver may engage in non-driving tasks like reading or sleeping.

However, the current seating configuration and positioning is conventional with all seats facing forward making it difficult



Figure 3. In-vehicle GPS navigation (Hyatt, 2018)

to be involved in socializing activities. There are several factors which influence seating configuration, including trip purpose, trip length and the occupants with whom they are travelling (Jorlöv, Bohman, & Larsson, 2017).

Fixed seating makes it difficult for older adults or people with motor or visual disabilities to enter or exit a vehicle. It requires complex movements and high sensory-motor coordination. Moreover, older adults are characterized by reduced muscle strength and flexibility (National Institute on Aging, n.d.).



Figure 4. In-vehicle touchscreen display (Brady, 2006)

Use of Voice Recognition for System Interaction

Hands-free systems can support non-conventional secondary tasks such as text messaging or dialing by using speech-to-text or voice recognition technology. These systems operate by recognizing the user's spoken words and converting them into commands that can be used to accomplish various tasks. Such systems can work very well in conjunction with the in-vehicle communication and entertainment system (McCallum, Campbell, Richman, Brown, & Wiese, 2004).

Smartphones are often equipped with personal assistant software (e.g. Google Assistant, Siri) capable of voice-recognition, opening up the potential for these devices to function as nomadic in-vehicle communication and entertainment systems in place of more expensive integrated systems. However, occupants with speech impairments or auditory difficulties may have challenges in using the technology to their advantage. Irrespective of the integrated system or the type of smartphone available, occupants will find it difficult to interact with the autonomous vehicle using voice recognition technology.

Multi-Function Seating Controls

Most user controls within a car are visible to the occupant and within easy reach, making them easy to access, understand

and use. Seat adjustment controls have, traditionally, been located on the side of the seat base. There is a correlation between reachability and viewability of the placement of the seat adjustment controls; the placement of the controls at the outer side of the seat seem to be advantageous for reachability, whilst the placement in the door seem to favor viewability (Darrell & Norrblom, 2017).

Occupants with motor impairments may face challenges associated with body positioning to optimize sitting comfort and access to vehicle controls and displays. These requirements are necessary for reliable and safe completion of various operations associated with the task of driving. However, seat adjustment control being positioned in a cluttered way and their location being hard to reach, make ineffective interaction with the system for the people with motor disabilities.

DISCUSSION

While self-driving vehicles are a potentially transformation technology we argue that within the current paradigm, absent concrete guidance for accessibility, these vehicles are being designed in a manner that may render them inaccessible for many persons with disabilities and older adults. Specifically missing, we argue, is guidance that specifically describes what constitutes accessibility. In its place is proliferating a series of solutions to design problems which we refer to as anti-patterns; borrowing language from object-oriented programming. Within this work we seek to draw attention to these anti-patterns in an attempt to highlight how these common approaches may serve as de factor barriers to the use of self-driving vehicles by disabled persons and older adults. Work that highlights accessibility issues in this regard will become increasingly critical as self-driving vehicle technologies begin to become commercially available. This work contributes to the understanding of what constitutes accessible design for persons with disabilities and older adults in their use of self-driving vehicles and may further discussions around the concept of anti-patterns as a theoretical lens through which design may be analyzed.

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