'Trust me – I'm AutoCAB': Using natural language interfaces to improve the trust and acceptance of level 4/5 autonomous vehicles

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ABSTRACT

A simulator study explored the use of a natural language interface (NLI) to improve the trust and acceptance of level 4/5 connected/autonomous vehicles. Twenty-three participants undertook three journeys, each lasting approximately 7 minutes. Journeys were framed as different 'Taxi of the future' scenarios, with the vehicle, serving as both the taxi and driver/assistant, transporting participants autonomously to a predefined destination. Participants were provided with one of two different interfaces ('traditional visual' and a NLI), designed to maximise passenger comfort, provide locally informed information and resolve journey-related problems encountered on route. The traditional interface communicated information visually using a touchscreen, whereas the NLI interacted with passengers using 'natural' spoken language. Interactions were limited to one type of interface for each journey, with experiences counterbalanced. For the purpose of the study, the NLI was created using a Wizard-of-Oz technique using an actor to mimic the natural language system. Given free-choice to select their preferred interface during the third drive, twenty participants chose the NLI. Subjective acceptance ratings revealed that participants considered the NLI as significantly more useful, also assigning significantly higher ratings of satisfaction and confidence compared to its traditional, visual counterpart. However, trust ratings were largely equivalent for both interfaces. Overall, results show that the NLI was preferred over traditional visual interfaces in an automated driving environment, supporting its use it future autonomous vehicles. Further work could explore how to adapt the linguistic interactions of natural language systems to also foster increased trust amongst users.

Keywords: Autonomous vehicles, Natural language assistant, Wizard-of-Oz, trust, acceptance.

1 INTRODUCTION

Trust has been described as an 'individual's willingness to depend on another party because of the characteristics of that party' (Rosseau et al, 1998), and is considered to be a major factor in the *acceptance* of technology in the automotive domain (Lee and See, 2004) – 'the degree to which an individual incorporates the system in his/her driving, or if the system is not available, intends to use it (Adell, 2009). The determinants of trust and acceptance in the context of humans' interactions with future autonomous vehicles are thus likely to be complex and expected to derive from various factors, including the perceived usefulness and perceived ease of use (Davis et al., 1989).

Previous research has explored human-human interactions as a viable model for enabling future system communications, reasoning that as speech is the primary means of social interaction amongst humans, its use as a method of system interaction offers designers a unique opportunity to tap into human evolutionary instincts and foster intuitive interactions (Large et al, 2017). These evolutionary instincts are evident in some of our earliest behaviours. Born already primed to speech, we become able to distinguish speech like sounds from our wider environment in early infancy. These skills are honed throughout our development, meaning as we grow we are increasingly able to extract socially relevant, salient and paralinguistic cues, even from limited exposure to speech, for example, making determinations about a speaker's gender and personality from the pitch, cadence and rate of their speech, using these linguistic markers to guide our subsequent actions (Nass & Brave, 2005). These speech related behaviours endure even when we are consciously aware that the speech we are attending to has a non-human source. Designers have subsequently exploited these evolutionary behaviours, designing systems with varying 'digital personalities' which change their language and vocal characteristics to influence user trust, performance and learning (Nass & Brave, 2005).

Speech based interfaces have previously been examined as a combatant to fatigue (Large et al, 2018), a mediator of human emotion (Nass et al, 2005) and as a means to reduce the 'gulf of evaluation' between human and system (Eriksson & Stanton,2017). These studies have shown that speech-based systems have the potential to improve driving performance and driver attitude when systems communicate using a voice consistent with the driver's current emotion (energetic system voice for happy drivers and subdued voice for upset drivers), and indicate an emerging preference and increasing expectation for natural language interactions over other traditional interfaces in the automotive domain (Large et al., 2017). Additionally, Eriksson and Stanton (2017) suggest that the employment of natural language interfaces within the driving automation paradigm can enhance human-system communication by providing timely, intuitive feedback to drivers, ensuring they are aware of current system status, informing users why the system has chosen a particular path of action, and what the next projected action will be. The authors liken such system communications to a 'chatty co-driver', explaining that natural language can be used to relay information about vehicle sensor limitations and potential obstructions in the roadway ensuring that users are continually kept in the control loop should automation failures arise, thereby reducing the likelihood of incident. This study represents a first step in the exploration of natural language autonomous vehicle interfaces which specifically aim to foster trust and ultimately promote system acceptance.

2 METHOD

Adapting the driving simulator to mimic a level 4/5 automated vehicle, we utilised a Wizard-of-Oz approach to explore how interactions with a natural language interface (NLI) might improve the trust and acceptance in connected and autonomous vehicles, compared to a traditional, visually-based interface (as a baseline condition). Twenty-three participants (19 male, 4 female), with an average age of 28.7 years (SD = 8.69), completed three simulated 'drives', which were framed as a 'Taxi of the future'. Each simulation took participants to a fictional destination (which was communicated to the participant prior to the journey), with the vehicle in autonomous mode and the participant seated in the drivers' seat of the simulator. As such, participants were informed that they were not required to make any primary control inputs or engage with the driving environment during any stage of each drive. In their first and second drives participants were required to cooperate with system-initiated interactions from two different interfaces, each of these interfaces were framed as a 'digital taxi assistant', as follows:

1. "AutoCAB" - NLI which guided drivers though scenarios by providing participants with news updates, passenger comfort interactions (e.g. music selection), facilitating email and calendar organisation/

scheduling, and finally offering assistance with emerging journey-related problems. Using a Wizard-of-Oz approach a male actor mimicked a natural language system via a video link within the driving simulator.

2. Traditional Interface - Used visual slides to offer matched assistance to passengers, ensuring that participants perceived both systems as having equivalent levels of functionality. Drivers interacted with the 'system' (with visual stimuli manually manipulated by the experimenter) using short verbal cues (e.g. 'yes', 'no', 'more information') akin to current voice activated systems within vehicles.

Participants were briefed of the capabilities of each interface and how best to interact with each system prior to commencing each simulation 'drive'. In the third and final drive, participants were required to select which format of the digital assistant they would prefer to accompany them (AutoCAB or Traditional interface). Participants completed trust in automation and system acceptance questionnaires after each simulated drive, which indicated their level of trust and acceptance of each assistance system. Ratings were elucidated by participants during post-trial interviews.

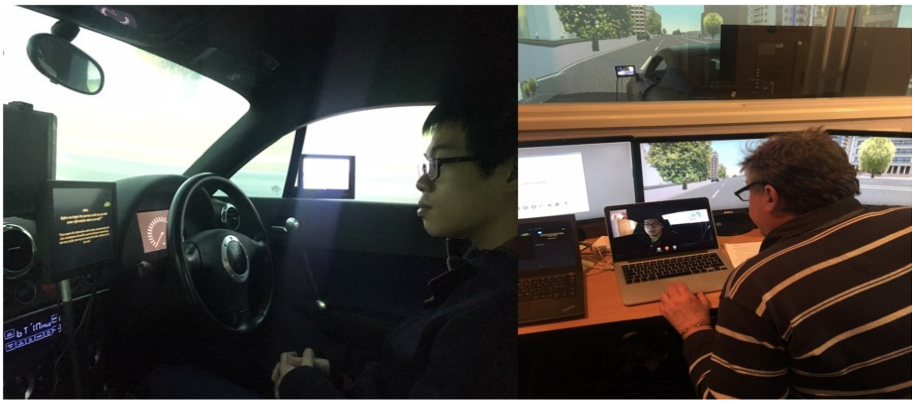

Figure 1 – Traditional interface (left) and Wizard-of-Oz setup (right) in which an actor mimicked an NLI interface

3 RESULTS

3.1 Acceptance data

After each simulator drive, participants were required to complete an acceptance questionnaire (Van der Laan, Heino & De Waard, 1997) which assessed system acceptance across two dimensions, perceived usefulness and satisfaction associated with system interactions.

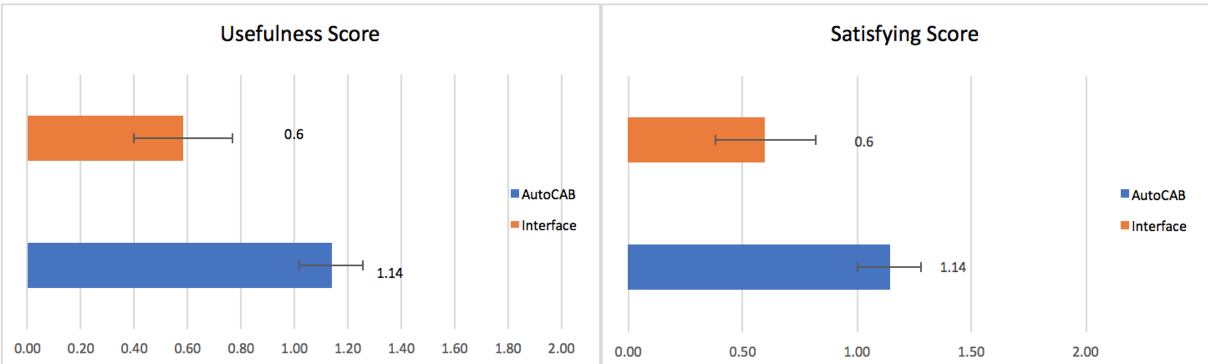

Figure 2 – Perceived usefulness and satisfying scores of participants after interactions with the 'AutoCAB' and Traditional interface ('Interface')

A Wilcoxon signed ranks tests indicated that participants perceived the AutoCAB interface to be significantly more useful (Z = -3.34, P<.001) than the traditional interface. Similarly, participants also indicated that interactions with the AutoCAB interface were significantly more satisfying (Z = -2.32, P<.020) than the traditional interface.

3.2 Trust Data

Participants also completed a questionnaire which examined the level of trust between people and automated systems (Jian, Bisantz, & Drury, 2000). This assesses trust across a range of factors (Figure 3). A series of Wilcoxon signed ranks tests indicated both the AutoCAB and traditional interface were statistically equivalent across a number of aspects of trust. However, participants did report significantly higher levels of confidence in the AutoCAB (mean = 5.5) interface compared to the traditional interface (mean = 4.8) (Z=2.43, p=0.015).

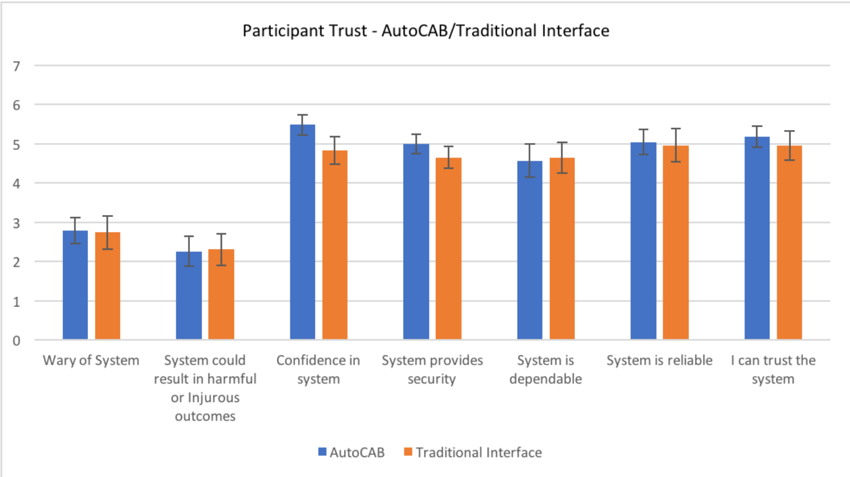

Figure 3 – Participant trust ratings for the AutoCAB NLI and Traditional Interface

3.3 Choice drive

Overall results indicate that the natural language 'AutoCAB' interface was the preferred assistance system, with 20 out of the 23 participants selecting the NLI interface for their third, choice drive. Participants provided insight into the reasons for their interface preference in post-trial participants interviews. Those drivers who selected the AutoCAB stated that natural language communication was more intuitive, allowing them to communicate freely, without following defined system commands (P3). This free-flowing communication fostered feelings of trust in some participants (P11), meaning they felt more at ease when the car simulated a 'system sensor failure' as part of an experimental trust challenge. Additionally, interactions with the NLI system were perceived as being more 'assisting' (P13) and less onerous on the human passenger.

P11 – I prefer talking to people, I guess it comes down to feeling like you're being heard. If anything happened like a breakdown I would want to be able to communicate that with system – If it was just the screen I would feel trapped in a box.

P13 – I felt that the first one (the NLI) was more trustable than the second. Maybe it was because I heard a human voice talking to me, I felt as if something was taking care of everything for me.

However, participant 12 did make the distinction that the social environment of the car could influence a person's willingness to engage with an NLI system, offering that such systems such be adaptable, allowing the passenger to choose their level of interaction.

P12 - I would prefer to interact via speech. Though, I guess it depends if you're alone…. If you're with someone, maybe not

Alternatively, those participants who selected to interact with the traditional interface in their third drive cited trust concerns (P2) and the potential sharing of information as reasons for their interface selection. However, this was not true for all participants selecting the traditional interface. Participant 6 suggested that their own social introversion meant that, any speech-based interactions were not preferred.

P2 – I don't like voice based systems for trust reasons….You don't know what's in the fine print (of systems) and what's it's recording. …it was disingenuous, it was obviously just using common points of conversation and using me as a data point.

P6 – I'm quite introverted. I don't want to interact with people and machines – it's not a trust thing.

4 DISCUSSION

The study compared the use of a NLI and a traditional visual interface to support drivers during automated driving, using their subjective ratings of trust and acceptance, and usage preference, as measures. Results indicated that overall, the natural language system was preferred to the traditional interface, inspiring higher ratings of usefulness, and confidence, and was found to be more satisfying; the NLI was also most commonly chosen during the 'free-choice' drive. Using natural language enables vehicle occupants to interact with the system without the need for training in specific verbal prompts or complex manual interactions, and reduces the visual demand associated with using the system, and this is likely to have influenced drivers' preferences and ratings. Although participants were not actually driving, they would likely prefer to direct their visual attention towards secondary activities in a fully autonomous vehicle, and therefore minimising visual demand remains an important consideration. Additionally, the presence of a 'human' voice, and the conversational exchanges that ensued, is likely to have inspired perceptions of 'humanness' associated with the NLI. This 'familiarity' may have encouraged a more pleasant experience using the NLI, putting drivers at ease, and inspiring greater confidence that the system was 'managing' the journey effectively, as a fellow human might.

Nevertheless, some results did not fully support the aims of our study, i.e. there were no significant differences revealed in the level of subjective trust associated with the different interfaces. It is feasible that given the nature of the study design (i.e. with both experiences occurring in the simulator and in close succession), participants may have believed that both interfaces (NLI and traditional) were simply two manifestations of the same 'system', and as such, any differences were solely in the modality of presentation rather than in the underlying 'intelligence' of the system. Consequently, the information was considered to be equally 'trustworthy' in both situations. In contrast, the heightened confidence ratings associated with the NLI may be attributed to the paralinguistic cues that are naturally contained within speech and can modify the meaning and perception of vocal utterances. As such, participants may have drawn different interpretations of the information presented visually and orally, inspiring different ratings of confidence, even when the content of the utterances was the same. Additionally, heightened confidence ratings may be related to the participant's ability to gain timely feedback on system status, and the ease with which they could interrogate the system. This is supported by Eriksson & Stanton (2017), who highlighted that clarity of system status through speech can enhance communication and individual perceptions of successful interactions.

Overall, the study provides some encouraging results that support the use of NLIs to increase the acceptance of future autonomous vehicles, although further work is required to understand the implications for trust. In particular, future work should look at a wider range of use-cases (for example, employing 'trust challenges' to further test participants' relationship with the system). In addition, the fidelity and validity of the 'driverless' experience could be improved, for example, by modifying the vehicle interior (removing primary controls etc. which would likely not exist in a fully autonomous vehicle, but were notably present during our study). In addition, further investigations could explore the linguistic properties and lexical content of utterances, with the aim of increasing trust using learned techniques from human-human interactions.

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