

Functioning E-Textile Sensors for Car Infotainment Applications [†]

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Abstract: Car interiors are envisioned to be living spaces that support a variety of non-driving-related activities. Previous work focuses on enhancing driving-related functions, performance and safety. By developing textile-based sensors, we focus on enabling non-driving activities integrated in the car interior and supporting a richer user experience. In this paper, we introduce an array of new applications using e-textile sensors to the design space of car interiors. Our functional prototypes implement hand interactions (such as press and double tap gestures) on the leather or fabric of the steering wheel and back of the head rest. We then propose applications for these sensors to control media, car windows, and air-conditioning. Overall, the paper contributes a novel tactile input modality to support drivers and empower backseat passengers.

Keywords: human-computer-interaction; human-vehicle interaction; e-textiles; user experience; non-driving activities; car interiors



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1. Introduction

In the past, in-car interaction modalities have been restricted to traditional mechanical gear, knobs, buttons and handles. Lately, graphical user interfaces (GUIs) were introduced to commercial cars, including dialogue-box representations and speech-based input. Today, novel technologies create many opportunities for designing valuable and attractive in-car user interfaces. For instance, designing for a richer experience is starting to shape technologies such as automated driving, creating unprecedented opportunities for designing further comforting and entertaining in-car user interfaces. For instance, designing for a richer experience is starting to shape technologies that assist the user in driving, such as navigation systems or voice assistant systems, where the user interface is essential to the way people perceive the driving experience. Scholars consider that in the near future cars will transform into living spaces [1] rather than just means of transportation. In that sense, the interior designs of cars should consequently be revisited, with interactivity being embedded ubiquitously within the interior fabric itself. Therefore, our motivation and inspiration in this project stems from the 'interioraction' concept [2] that supports the blend of both interaction design and interior design into a seamless union. New means for user interface development and interaction design are required, as the number of factors influencing the design space for automotive user interfaces increases [3]. This paper discusses novel interactions through parts of the car consisting of textiles such as fabric or leather, which constitutes a great potential opportunity to utilize these parts of the car for human-vehicle interactions. In the rest of the paper, we first discuss some of the existing tactile user interfaces for in-car systems in the Background section. Second, we mention some of the recent advances in e-textiles that can be incorporated in cars for in-car interactions, and finally we explore some of the possible applications of e-textiles in cars regarding non-driving activities and how e-textiles can potentially improve user experience.

2. Background

To enhance user experience inside the vehicle, various in-car systems have been designed and developed to fulfill the requirements of passengers during the journey, such as, for example, navigation systems, media players and multi-functional displays. As we know, all of these in-car systems in a manually-driven context are distracting and focus-demanding; thus, it is in opposition to the primary task of driving, which requires extensive visual and cognitive attention. As a result, engaging a driver with various auditory and visual demanding systems could cause devastating crashes [4]. To redeem this issue of distracting systems, many researchers have proposed to increase the modality of input and output channels so that drivers do not have to divide their visual attention between the primary task and in-vehicle systems.

One of the less employed interaction methods in vehicles is a tactile sensory modality that does not interfere with driving [5]. Many papers have discussed the effects of this modality on driving performance and user experience [4–6]. The results illustrate that there is no significant difference between the tactile display and conventional systems (audio/visual-based) in terms of performance; however, the user experience has improved: participants considered getting feedback from the tactile display to be comfortable and pleasant [4]. The enhanced interaction style was the result of an improvement in the usability and ease of use goals, not in the experiential values [7] such as the playful, engaging, aesthetic and pleasant aspects of the user experience.

Derived from the literature, the usage of textiles inside cars for in-car interactions is confined to the integration of tactile feedback (e.g., push, shear force) into the steering wheel or seat for navigational cues or notifications [8,9]. These tactile-based interfaces were only confined to drivers for assisting driving-related tasks. By using e-textile fabrication methods, we can design interfaces not only for drivers but also for ‘passengers’, who have been predominantly neglected when designing in-car interactions, to enhance their user experience in terms of experiential values and offer an excellent opportunity to embed seamless, less focus-demanding, playful interactions by employing e-textiles techniques.

3. Sensing and Actuation

With the rapid advance of e-textiles in recent years, we can transform textile components into interactive fabric that can receive inputs and give outputs without being integrated with bulky electronics.

Advancements in different kinds of e-textile input sensors such as pressure-sensitive textile sensors, conductive threads/fabrics, and advanced fabrication methods make it feasible to fabricate textile capacitive/resistive touchpads [10] and deformable textile sensors [11] to detect surface and deformation gestures efficiently and reliably. As for textile interfaces for output modality, there has been extensive progress on light-emitting textiles, e.g., the integration of inorganic printed LEDs [12], Ultraviolet Organic Light-Emitting Electrochemical Cells (UV OLECs) [13], fabric audio speakers [14] and shape-changing fabrics [15], to embed visual feedback through the textile for in-car interactions. Using these technologies, many in-car interactions are practicable through e-textiles, and we explore some of them in the next section.

4. Proposed Applications

As we transition towards automated cars and they are becoming a space for many entertainment and non-driving activities, more user interfaces are being added to the vehicle interior. As a result, this number of interfaces may be disruptive and sometimes annoying. Because of their pervasive nature in our daily lives and their vast presence in the car interior, in-car textiles offer us this great opportunity to morph the car interior into an interactive interior using e-textile disciplines. By reducing interfaces in the center stack and embedding them in the interior by utilizing ‘interioractive’ design considerations [2], the car interior would have many resemblances to a living space and could be more dynamic and adaptable to user needs, which could stimulate more pleasurable in-car interactions

that could benefit passengers/drivers using manually driven cars and automated cars in terms of user experience.

4.1. Steering Wheel E-Textile Interaction

In manually driven cars, drivers are supposed to concentrate on the roads; therefore, interactions with in-car functions should require as little visual attention as possible. Considering this fact, the steering wheel center would be a perfect space for eyes-free interactions with the fabric of the steering wheel for non-driving tasks. In Figure 1, the proposed intuitive gestures for interacting with the media player, window and air conditioning through the center of the steering wheel have been proposed. According to Pflöging et al. [16], who embedded touch screens in the center of the steering wheel to capture in-car functions, the most repeated gestures were sliding up/down or up/down. Their results suggest that these gestures are easy to execute and remember.

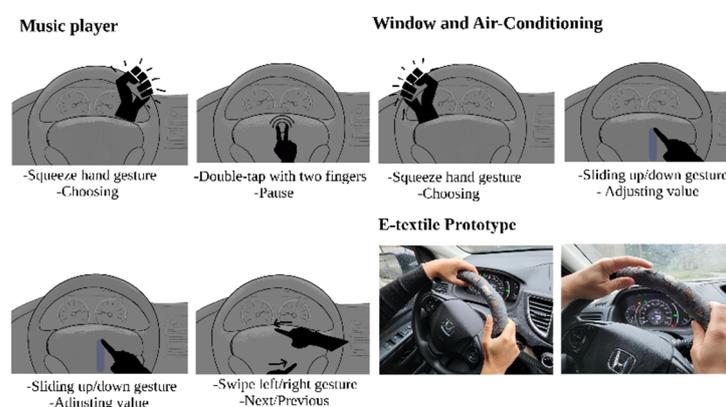


Figure 1. Illustrated gestures that can be executed on a steering wheel to control a media player, window and A/C, and the fabricated e-textile prototype.

Based on previous work, we propose utilizing sliding gestures on the fabric to adjust the value of the three in-car systems: media player, windows and air conditioning. To choose which system one intends to interact with, voice commands could be used for activation, while hand gestures are less cognitively demanding in terms of learnability, which is more satisfactory. The hand squeeze gesture is also an intuitive gesture that can be executed for activation. The steering wheel can be divided into four sections, and each section corresponds to a specific system. An e-textile prototype for the steering wheel has been fabricated and is depicted in Figure 1 as a proof of concept.

This prototype was developed using Knit Jersey conductive fabric from Adafruit and a sewing machine for stitching the conductive fabric to the base fabric. The conductive fabric is connected to the LilyPad microcontroller board through soldered silver-plated conductive thread from Karl-Grimm stitched on the conductive fabric as seams. HID (Human Interface Devices) control keys for controlling the multi-media player are sent to the media player using the Adafruit Bluefruit LE UART Friend module attached to the LilyPad board after detecting the executed gesture on conductive fabrics.

4.2. Headrest E-Textile Interaction

Since car interior textiles are within the range of passengers' hands, they can be a new modality for in-car interactions. The back of the headrest is one of the areas in cars that is mainly used for touch screens, and to the best of our knowledge, no prior work has explored this space as an opportunity for embedding e-textiles and transforming it into interactive fabric for in-car interactions, especially for passengers. E-textiles enable us to integrate digital capabilities behind and/or within fabrics and keep the car interior as seamless as possible, allowing interior designers of future automated vehicles to play with possibilities without designing encompassing screen-based interfaces. In Figure 2, the

proposed gestures for passengers to interact with the three systems of the media player, window and air conditioning are illustrated. Unlike steering wheel gestures designed for drivers, headrest gestures designed for backseat passengers can utilize their visual channel. Visual feedback can also be possible with the usage of thermochromic threads or LED/UV OLECs. In Figure 2, the possible interactions are illustrated and the e-textile prototype has been embedded into the back of the headrest as a proof of concept. The e-textile interface can be enhanced to detect various gestures with embedded visual feedbacks. The fabrication and development process for this prototype is the same as for the previous prototype, with the exception of its visual design; here, it is designed for passengers' in-car interactions to control a media player.

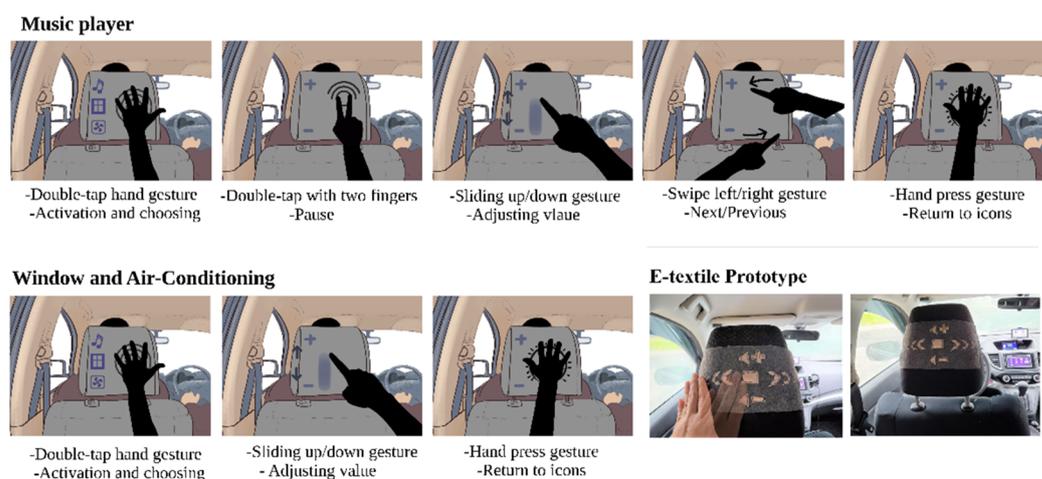


Figure 2. Illustrated gestures that can be executed on the back of the headrest to control a media player, window and A/C, and the fabricated e-textile prototype.

5. Conclusions

This paper discusses how e-textiles could be integrated into the human vehicle interaction domain, particularly as an input modality for both drivers and backseat passengers—the latter not having been explored before. We introduced a number of novel applications of e-textile interactions seamlessly embedded within car fabrics or leather surfaces. On both the steering wheel and the back of the headrest, we showed our proposed e-textile input interfaces as tactile screenless means of controlling multimedia, windows and A/C inside the car. By highlighting the gap between the e-textiles and Human-Vehicle Interaction (HVI) areas, we hope more research will be done in this area that evaluates how people interact with and perceive such tactile e-textile applications. As we transition towards fully automated vehicles (driving tasks will be removed from drivers, and all tasks will be non-driving tasks), more and more opportunities will arise for drivers' and passengers' in-car interactions through e-textiles. We hope to inspire future work around the situated use of such applications and their support of social engagement amongst family members or those with children and amongst strangers sharing or car-pooling, while also empowering backseat users using online taxi services.

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