Comparison of E-Ink and OLED Screens as Train Seat Displays: A User Study

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Abstract. This study was designed to provide an evaluation of two types of train seat displays (OLED and E-ink), from a user-centred perspective. Numerous factors influence the decisions on which display to use, such as costs or energy use. It is also important to consider human factors aspects like readability and user preferences. To provide some real-world insights into these issues we designed a pilot study to compare both displays. Participants were asked to give their impressions and respond to questions during a semi-structured interview process, when they were presented with both displays. Results show that participants favour the OLED display overall as it is easily noticeable in different light conditions. However, some aspects of the E-ink are preferred: it is easier to read and understand. We conclude that research with real users is extremely important when designing and defining hardware to be used during the implementation of intelligent transport systems.

Keywords: Passenger information system · Seat displays · User preferences User centred design · Usability · User experience

1 Introduction

User experience on board of trains can be affected by diverse factors, such as problems during the boarding process [1], difficulties to find reserved seats [2] or the lack of information about where the available seats are [3]. Passenger information systems in stations, on board of trains or on mobile devices can minimise some of these problems and improve the journey experience. Seat displays can convey diverse information such as seat number, reservation status, origin and destination and even passenger names. Technological innovations now permit the integration of these displays with online services and have the information updated in real time. User interfaces should convey the information and provide the interaction in a way that does not require high levels of cognition, attention and memory [4]. Screens should be easy to read and give information that is useful, in the attempt to foster usability and enhance user experience [5].

T. Kováčiková et al. (Eds.): INTSYS 2017, LNICST 222, pp. 294–300, 2018.
https://doi.org/10.1007/978-3-319-93710-6_30

This study considers two different types of displays that can be used in future installations, either to be fitted on new trains or to be retrofitted on existing rolling stock. One of the options is the electronic paper display (EPD or E-ink), a popular technology used on e-readers. Previous research compared e-readers and regular paper and indicated that they are fairly similar in terms of legibility, and that in specific circumstances the e-reader may even be better [6]. Other positive characteristic of E-ink is the electricity use: these screens consume no power while the image is static and only require energy when the image to be displayed is being updated. These displays are an interesting option for places where there is minimal power supply, for example if they are to be powered by micro energy harvesting [7]. E-inks, in combination with low energy Bluetooth, is considered as a viable option on board of trains to minimise installation costs and disruption, especially if retrofitting these displays into existing trains, in order to avoid the need for rewiring entire coaches.

Negative aspects include the fact that E-ink displays are slow to update and can take a few seconds to fully refresh the screen. It is also important to note that these screens have no backlight for viewing in low light conditions, so there must be sufficient ambient light for the screen to be readable. This may not be an issue in a train carriage, which always have a reasonable level of ambient light.

The other option are the OLED (organic light-emitting diode) displays. These use higher power than E-ink as they produce light directly through the illuminated pixels on the screen. OLED displays are already commonly used in the rail industry as passenger information systems, usually of white or green text over a black background. Although there are previous research on the readability of E-ink and OLED/LCD displays [8], those concentrate on the analysis of reading performance of text books. The question persists for the application on board of trains. Therefore, this study was

Table 1. Some criteria influencing display choice

Variable	Determining factors to choose between E-ink and OLED
Financial	Costs to implement, running costs, need for maintenance, longevity and the deterioration rate
Data transfer	Requirements in terms of amount of information to be transferred and frequency of data transfer
Energy use	There may be the need for low energy consumption, for example if using energy harvesting methods to power the devices
Rolling stock	Existing trains may have different requirements in relation to displays, given different housings, available spaces, existing wirings, etc.
Regulations	There are rules and guidelines for type and placement of displays, which will affect choice
Environment	The impact of the display on the environment should be considered, in terms of energy use, raw materials and e-waste
Readability	The information on the display may be read better in one display than the other, according to light levels, contrast and glare
User preferences	Passengers may prefer one device due to a range of factors, not only the ergonomics limitations but also how it feels and looks

set to define what is the best display to use for a seat information screen, between E-ink and OLED.

When planning the implementation of new technologies, a range of factors can come into play and influence the decision making process. There are variables on the financial, technical, regulatory and ergonomic spheres, which would affect the choices of on board information screens. Each of these variables are determined by a range of factors, and we present some of those in Table 1 above.

2 Methods

Both displays were encased in cardboard boxes with only the user-facing part of the display visible through a window cut on the box. These were deliberately rough-looking low-resolution prototypes, to motivate users to speak more freely as opposed to a finished product [5], which can cause people to think that the item is already built and therefore there is not much that can be changed. The displays were hung on the wall (Fig. 2, right), where the OLED display was powered via a micro-USB cable connected to a regular phone power bank. This solution was adopted to prevent the need of power cords feeding the display. The E-ink display required no power supply since the contents had been pre-recorded. Participants were recruited among staff and interns of the Warwick Manufacturing Group, University of Warwick.

The test occurred in an office with constant (artificial) light levels, roughly reproducing the light levels in covered stations or tunnels. To quantify this brightness, a measurement was made on board of trains, where a smartphone application was used to evaluate the light levels. Two recordings were made for each data point. Each recording was an average of the light data across 30 s. This data is presented in Fig. 1. The starting and ending data points are stations (Birmingham New Street [UK], underground, and Derby [UK], partially covered) where the coach was illuminated mainly through its artificial lights. The middle points represent the light levels when the train went through open fields on a sunny or partially clouded afternoon. The same application was used to define how to simulate these two extreme light conditions in the experimental setting.

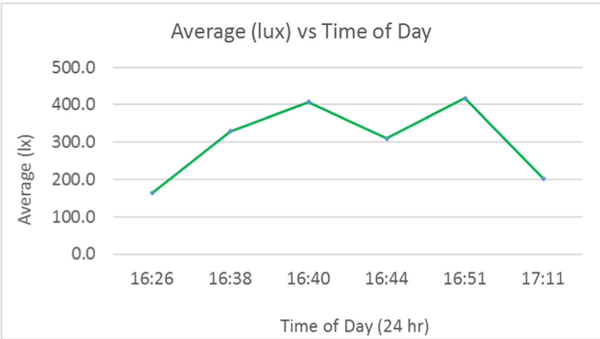

Fig. 1. Light measurements on board of a train

Fig. 2. (L) The two displays in the casing used during the study and (R) the study setting

Six participants were invited to test the two displays. Genders were distributed equally, and ages ranged from 19 to 33. Participants were asked to stand about one metre away from the wall where the displays would be placed. A series of open-ended questions were asked so participants could give their impressions about one display first, and then this display would be replaced with the second option. The trials consisted of a counter-balanced A-B/B-A design [9] where half of the subjects started with the OLED and the other half with the E-ink display. This alternation was used to minimize biases that could emerge from the order of presentation of displays, which could influence the results.

The process was guided by a semi-structured questionnaire with which we asked: What do you think about this display? What are your impressions in terms of readability/Contrast/the colour of the text and background/the amount of information displayed/the identification of the display in the context of the background? Then, the displays would be placed side-by-side and the following questions asked: Which display do you prefer? Why do you prefer this display? Finally, the blinds were open to let daylight into the room, and participants had another chance to evaluate readability with different levels of light, contrast and glare.

Interviews were recorded, transcribed and imported into a software for qualitative data analysis. Participant's statements informed the themes used during the analysis and were organized "to find repeated patterns of meaning" [10]. This organization helped the qualitative data analysis and facilitated the extraction of specific quotes for relevant themes as seen in the results section below.

3 Results and Discussion

Four of the participants preferred the OLED display, whereas two voted for the E-ink on the overall evaluation. When asked to explain the reason for their choices, participants mentioned a range of reasons, summarised in Table 2. The main reason for passengers preferring the OLED is that it is immediately noticeable, as mentioned by five participants. For example, participant 2 (P2) said that "*OLED stands out from background and other objects… I notice it more easily on fast viewing*". P6 adds their concerns as why it is important to distinguish the display quickly:

> *As a passenger on a train under stress and pressure from carrying luggage and time constraints, it may be easier to see and read in a rush the text on this display. I always double-check the seat from the screens. I think it is easier to make sure you are in the right seat from this display.*

Four participants also preferred the contrast levels of the OLED, and added that the information on the screen is not affected as much by light levels. After the blinds were opened, P3 said that "[the readability] *remains same as before*". P6 complements: "*I don't think the light impacts the readability of the text that much with some natural light*".

Table 2. Comparison of both displays, according to participants' responses

OLED	Characteristics
Positives	Immediately noticeable Good contrast Readability does not change with different light levels
Negatives	Poor formatting of text, only four lines of text Glare in bright environments Hard to read
E-ink	Characteristics
Positives	Information is clear, easy to read, text spaced out Good in bright environment Good contrast
Negatives	Hard to notice the display, does not stand out Difficult to notice the information on the screen

Although OLED was preferred, it also presented drawbacks, especially because the display tested had only four lines of text. This was a noticeable disadvantage in comparison with the E-ink, which had six lines. Consequently, five participants complained about the information layout: "*The text is closer together on the screen, and formatting not as good as the other* [E-ink]*, so it's harder to read slightly*" (P3). P5 complements saying that "*it's slightly harder to understand the text*". Another disadvantage is that, since the background display is black, it can present more glare than white backgrounds. Two participants mentioned that it is harder to read from a white text on black background than the opposite.

Participants recognised some advantages of the E-ink, primarily the information layout. "*It is very clear. It has all the information I want on the display. I want to know where the seat is reserved from and location, this is quite easy to understand*" (P1). P4 adds that the E-ink is "*nicer to look at, it is spaced out well*". Another advantage is that the performance is not deteriorated when the light levels increase. The E-ink seemed to be "*more readable under brighter conditions*" (P3). However, the negative aspect of the E-ink is mainly that it is harder to find in the context of a train coach, as reported by four participants. P4 declared that "*It's not as good as the other as it's not lit up*". P6 complemented: "*It doesn't stand out as well in comparison to the first one*". Participants also added that they need to see the information on the screen more easily, suggesting layout changes such as "*some words could be bigger to highlight importance to consumers*" (P3) or that "*it's not easy to see quickly whether a seat is reserved or not. The addition of colour could be useful*" (P1). One participant also added that since this display looks like paper, it does not seem to be up-to-date.

4 Conclusions

We conclude that participants want to recognise seat displays quickly and understand the information, to minimise the mental load [4] during the boarding process. As described by previous research, the process of boarding and finding a seat is often stressful, and a well-designed seat display "can minimise the insecurities during the boarding process" [2]. Therefore, displays need to stand out and be easily readable. Displays should also be perceived as containing up-to-date information, especially if as part of dynamic seat reservation systems [11]. A combination of positive aspects from both screens could result in the ideal display, such as a larger OLED with text arranged nicely. E-ink could be combined with LEDs to display a traffic light system to make it easier for passengers to see the seat availability at a distance. Alternatively, colour E-ink may solve some concerns from users, highlight important information and provide a better hierarchy of text.

We understand that this study presents limitations. As it had only six participants, it may not be suitable for quantifying preferences, although practitioners defend that as little as one participant can provide to the design team the major usability problems [5]. To minimise the shortcomings of a small sample size, the contribution from this study was focused on the qualitative data from interviews. We believe that, as a pilot study, it gives scope for conducting further trials. Future studies could test other displays, casings and background colours to evaluate their performance in different contexts and scenarios. Studies could also recruit a larger sample and include more diverse user groups, as age and cultural backgrounds may affect perceptions and abilities. It could also use scientific equipment like photometers and luminance meters to provide precise quantitative measurements of ambient light and screen contrast [6]. This data would be useful when combined with subjective evaluations from interviews to provide a complete picture of the physical characteristics of each screen and the correspondent user perceptions.

Acknowledgments. This research is part of the "CLoSeR: Customer Loyalty and Dynamic Seat Reservation System" project, funded by RSSB/Innovate UK (Grant No 102483). This project was selected through the competition 'Enhancing Customer Experience in Rail'. Partners in this project are the University of Warwick, Cranfield University and four industry partners: Unipart Rail, TrainFX, Loyalty Prime and Great Western Railway. The authors would like to thank all participants who donated their time to take part in this study.

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