Can Multimodal Interaction Support Older Adults in Using Mobile Devices? The ECOMODE Study

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Abstract

Several studies investigated the potentialities of multimodal interfaces for improving accessibility for older people. This paper presents a study that evaluated the user experience of sixty people who worked with a tablet PC running the ECOMODE technology. This technology consists of an event-driven compressive vision algorithm, that allows the realization of a new generation of low-power cameras, able to elaborate real-time vocal- and video-inputs. The users interact with the applications on the tablet PC using mid-air hand gestures and vocal commands. Even if the ECOMODE technology suffers from some technical limitations, older people appreciated the proposed multimodal interaction mode. The results pointed out that the ECOMODE technology was considered to be particularly promising for daily tasks involving communication, such as placing calls, sending and listening to audio and messages, and taking and sharing pictures. It also seems effective in navigating archives, such as pictures, audio, or music databases.

1 Introduction

Interfaces that allow multiple perceptual processes through parallel sensory channels enhance user interaction with computers [Brewster S.A., 1994]. Several studies investigated the potentialities of these interfaces for improving accessibility for diverse users, including older people (eg. [Naumann A.B., 2010]; [Ferron, 2015]). However, multimodal interfaces that specifically combine speech and mid-air gesture interaction are rarely explored in the literature.

In this paper, we present a study that evaluated the experience of a group of older adults who had to operate a tablet PC using both mid-air gestures and vocal commands.

More specifically, they used the ECOMODE technology. The main aim of this evaluation was about the User eXperience (UX).

2 The ECOMODE project

ECOMODE (Event-Driven Compressive Vision for Multimodal Interaction with Mobile Devices) is a four-year project funded by the EU H2020 ICT22 call. The main goal of the project was to develop multimodal human-computer interfaces for mobile devices where the interaction is based on a combination of vocal commands and mid-air hand gestures, specifically addressing the needs of older adults and visually impaired people.

The project exploited the EDC (Event Driven Compressive) algorithm to realize a new generation of low-power cameras (Figure 1), able to elaborate real-time vocal- and video inputs.

Figure 1: *The ECOMODE prototype running on tablet PC (left) and a user during the evaluation (right).*

A user-centered design based on a participatory approach [Sanders, 2002] was followed by involving groups of end-users along the entire design process, from the collection of the initial requirements to the final summative evaluation. In this paper, we report on the latter one phase.

3 Study with elderly people

This study aimed to evaluate the UX of older adults with the ECOMODE system: a software application - the facilitator - that allowed the navigation of photo archives and audio podcasts using mid-air gestures and vocal commands.

3.1 Participants

The summative evaluation study of the ECOMODE facilitator involved a total of 60 older adults (gender composition: 35 females and 25 males). The age range varied from a minimum of 61 years old to a maximum of 87 years old, with an overall average age of 73.09 years old (SD= 6.87). Participants with an age in the range of 60-70 made up 45% of the sample, 27% of the sample had an age-range between 70 and 75 years, and a considerable part (28%) included also older-old participants (age 75+). Participants were generally right-handed (92%), but the sample included also some left-handed and ambidextrous participants.

On average, the sample reported a mild positive attitude toward technology (M= 3.5, SD= 0.9 - considering a scale between 1 "Very negative attitude" and 5 "Very positive attitude"), with a minimum value of 1.4 and a maximum value of 5. The score is in line with the value observed in other studies with a similar population [Zambianchi, 2018].

Most of the participants (75%) owned and used frequently a smartphone. People who did not own a smartphone used a traditional mobile phone with a physical keyboard. About a third of the sample (35%) owned a computer and used it almost every day, while 28% owned and used tablet devices. More than half of the participants (60%) used Internet every day, and 68% used email. Concerning WhatsApp, 72% of the total sample reported using it frequently, while 41% used Facebook. Fifteen people (25% of participants) reported to know about and have used a vocal assistant.

3.2 Procedure

This evaluation study was based on a between-subject design. Participants were randomly assigned to one of two command sets: simple and full set (Figure 2), different for the number and type of commands included to interact with the mobile device [Ferron, 2019]. We involved a pool of target users to reveal the best scenario for testing the ECOMODE technology.

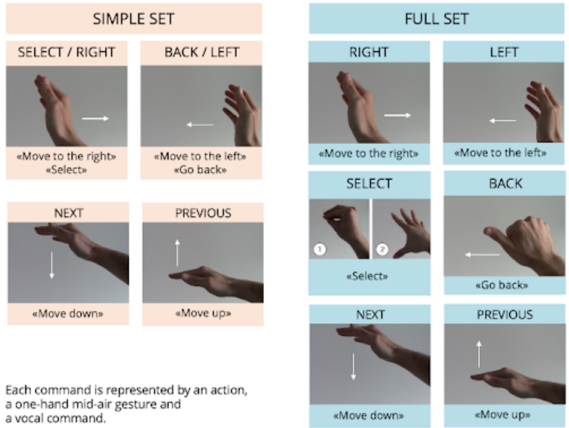

Figure 2: *Simple and full set of multimodal interaction commands.*

Using questionnaires and interviews, we found that the older adults appreciate the tablet device to take pictures when travelling or attending specific social events (e.g., birthday parties, anniversaries, art exhibitions, concerts). They also love using the tablet to read newspapers, navigate the Internet to search information, listen to music, podcast, etc.

Starting from the users' preferences and needs, two use cases were elaborated: 1) taking and sharing a picture and 2) listening to a podcast. Both are suited to test the ECOMODE technology in indoor and outdoor scenario with standing or sitting users. Due to time constraints, we decided to evaluate the ECOMODE facilitator only through the scenario "Listening a podcast". We considered two different contexts: the indoor context, participants listened to a cooking recipe, whereas in the outdoor context they listened to an audiobook. The order of the two scenarios was randomly assigned to each participant and counterbalanced. Each podcast had a maximum duration of about 2 minutes. In both cases, the participant was asked to listen to the audio for a while, then pause, and then listen again.

In the indoor scenario, the participant was standing and the ECOMODE tablet device was placed on a support on a kitchen shelf, close to the stove. In the outdoor scenario, the participant was sitting on a bench in the garden, holding the tablet with one hand while performing the interaction gesture with the other one.

The experimental session itself included the following steps:

- Welcome
- Task explanation
- Signing of consent form
- Gathering of personal information, such as age, handedness, attitudes to and use of technology
- Training session: Participants were introduced to the ECOMODE prototype by receiving a de-

scription of the application and of the interaction commands. Such commands were firstly showed through the tutorial video, secondly performed by the experimenter, and finally tried by the participants themselves that could navigate through the interface guided step by step by the experimenter. The latter also informed the participants about how to do the gestures (e.g., not too low, so that the hand was within the view of the ECOMODE camera) and what to avoid (e.g., to pass in front of the camera to position the hand on the top for performing the down gesture)
- Task1: Completion of a specified task in an Indoor condition (standing)
- Task2: Completion of a specified task in an Outdoor condition (sitting on a bench) with the order of tasks 1 and 2 counter-balanced
- Post-task questionnaires: after each task, the experimenter read aloud some questions about exertion, difficulty in carrying out the task, time spent on accomplishing the task and the satisfaction about the support (feedback) received by the system
- Post-session Questionnaire Interview: at the end of the experimental session, the experimenter read aloud the questions about the user experience and the participants provided their answers, giving a score for each of the 40 items. Comments regarding their interaction experience with the ECOMODE technology were gathered too.

The participants were offered a gift voucher to thank them for their participation.

3.3 Results and discussion

In this section, we present the main findings related to the reported evaluation. We focus here mainly on usability issues. Furthermore, few technical issues are also reported.
Command learning and execution: the simple set of command was generally better than the full set with respect to UX dimensions and overall system accuracy. The simple set was also considered easier to remember.
Holding the device: We observed a high variability on how users held the tablet PC (Figure 3). Even though the ECOMODE case includes a side support, users show different types of grasps. Form factor and physical affordances are crucial elements to be considered.

User experience and usability of the Facilitator: it is globally perceived as offering good usability and user experience. The highest scores are reached for certain UX dimensions such as Ease of Learning, Ease of Use, Likeability and Satisfaction. Physical and cognitive demands derived by the interaction with the Facilitator are generally scored as low, and the Annoyance dimension as well. The participants recognised

Figure 3: *User grasping the tablet with the whole hand (left), holding the corner (center) or placing a part of the device on the palm of the hand (right).*

the importance of such technology for several activities (making calls, listening audio material, taking and sharing pictures, navigating on Internet or archives of pictures, music, etc.).
Feedback and Feedforward mechanisms: the tested version of the Facilitator includes some interaction mechanism of feedback and feedforward. Feedback was provided by visual and audio messages. The summative evaluation showed that elderly users were aware of such feedback information and used them to evaluate their interaction (e.g., repeating a command if it was incorrectly recognised). However, users expressed the need for more informative feedback, for example suggesting which action to take, or having more specific indications on how to adjust the mid-air / vocal command.
Training and first-time use: Using the Facilitator does not require any technical skill (it can be used by novice users too). However, training sessions are needed to get the user to correctly perform the commands.
Role of user attitudes toward technology: The summative evaluation showed that a positive attitude toward technology is related to more positive opinions on the interaction with the system and perceived accuracy. This is in line with previous studies on the relationship between attitudes and acceptance of novel technologies [Porter, 2006], [Al-Gahtani, 1999].
Technical issues: We observed that certain environmental conditions influenced the interaction experience. For example, the presence of artificial light sources (such as fluorescent lamps or tubes), low-light environments, and moving backgrounds negatively influence the accuracy rate of the system. When the user interacts with the system while moving (e.g., walking), or even if they move their head when seated, the facilitator tends to detect events and commands even when they are not present. This causes a significant lack of control over the interaction. We also observed that users with hand tremors and shaking hands had more difficulties in holding the device firmly, in controlling the interaction, and in correctly performing the mid-air gestures.

4 Conclusions

In this paper we reported on a study with older people, aiming to analyze their interaction with a tablet PC using both mid-air gestures and vocal commands. A group of 60 older people was invited to navigate a photo and audio archive using the ECOMODE facilitator, an application whose core is an algorithm able to recognize real-time gestures and vocal commands using very little energy.

The ECOMODE technology suffers from some technical limitations, that were afterward reported to the developers who resolved them. Even if the facilitator was not perfectly working in recognizing gestures and commands in any environmental conditions, older people affirmed that they like using multimodal interaction based on hand mid-air gestures and simple vocal commands.

ECOMODE technology was considered to be particularly promising for tasks involving communication, such as placing calls, send and listen audio and messages, and taking and sharing pictures. Other usage scenarios were applications for domotic control, rehabilitation and physical therapy, and activities involving reading (e.g., multimodal e-book reader).

In conclusion, although with some technical limitations, from the study conducted during the ECOMODE project, the proposed multimodal interaction was overall perceived as positive by the older adults and facilitating the use of mobile devices, therefore supporting their communication, social inclusion and well-being.

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Interacting with E-waste in the Name of Ecology and Sound Art

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Abstract

This presentation introduces Sound Art from Scrap, a project based on the interaction occurring between sound art and discarded electric and electronic devices (EED) through the practice of circuit bending. The hypothesis at the ground of this project is that circuit bending has strong ecological meaning and, used in the context of ecological sound art, can boost the message conveyed by the artwork. After an introduction to the background relevant to this research, the project to date is reviewed.

Keywords: e-waste; ecology; interaction

1 Background

The production of waste is an increasing global problem which does not seem to invert the trend but, instead, appears doomed to a rapid increase [Chen et al., 2020]. The increasing global population and the emergence of new economies are perhaps the two most significant factors influencing this rise. These are often bonded to one another, populations typically grow fast in developing countries [Cleland, 2013] but they are usually not strong enough at an infrastructural, economic, political, and organisational level to manage correctly and efficiently the stream of waste [Guerrero et al., 2013, Muniafu & Otiato, 2010]; it comes clear, therefore, how dramatic and critical the situation is. Additionally, increasing living standards should be carefully considered. While this means that people can generally have easier access to, for example, services and goods, this also inevitably implies a massive boost in waste production [Song et al., 2015].

For many, the solution to this problem, or at least the best date option, seems to be to increase the usage of biodegradable or compostable materials and to increase the rate of waste recycling. However, these proposals, often loudly advertised and highlighted, not rarely end in being mere market strategies leveraging popular belief and wisdom. For example, in the case of bio and organic materials, if simply landfilled and not treated properly, end up generating methane (CH_4) and carbon dioxide (CO_2), which are well-known greenhouse gases greatly contributing to global warming [Ayodele et al., 2020]. Thus, this takes the shape of enlarging a problem while trying to solve another. Concerning recycling in general, instead, the crude truth is that our technologies and waste management systems are not advanced enough to support and perform efficient recycling of the waste [Liehu et al., 2022], not to mention that benefits of recycling are not significant if this practice fails in offsetting the amount of raw material required for producing new goods [Geyer et al., 2016], and that the materials themselves degrade after every recycling cycle [Mistry et al., 2018]. However, no intention to deprecate recycling and new materials here, as these can surely help to address and mitigate the problem. The core concept is that, ultimately, the best way to avoid waste is to implement best practices to avoid their production in the first place [Goodship, 2007].

1.1 E-waste

So far, we have only talked about solid and municipal waste. However, while this more general introduction can be applied generally to any waste category, in this paper we are dealing specifically with e-waste. As for the other types, e-waste represents a challenging and increasing global problem, with the main difference being that the latter are both sources of valuable materials and hazardous chemicals [Perkins et al., 2014, Robinson, 2009]. E-waste comprises all the EED that are discarded daily and, more often than not, replaced with brand-new ones. Two main issues arise from this cycle: on the one hand, the over-production of tonnes of e-waste, complex to recycle; on the other, the over-exploitation of rare and precious natural resources for building the devices [Robinson, 2009], amongst which iron, copper, gold, and platinum [Premalatha et al., 2014]. Thus, so far, except for the toxicity of this type of waste and the type of materials they are composed of, usually more precious and rare, there is not much difference between them and the common solid waste.

However, at a closer look, the two issues mentioned before—over-consumption of resources and over-production of e-waste—are closely bonded since one does not exist without the other. Old products would not be discarded if new products were not available and ready to take their place, and vice-versa. Digging and inspecting the matter further closer, however, it can be evidenced that everything leads to a single phenomenon, rooted in the culture of wealthy western countries and named consumerism. To simplify, companies, in need of a constant, and possibly increasing, income, have to have consumers constantly buying their products. As different companies are competing for the same market segment, this opens the way to fierce marketing and advertising campaigns, as well as the usage of the most different selling techniques. These latter include artificially creating the need, for the customers, to own a new product, and thus inducing them to buy it even when there is no real need [Flipo, 1986]. Parallel to this comes the encouragement, or at least the invite, to substitute over reuse, as well as discard over repair, and, to foster this, the longevity of the devices, given by a combination of their functionalities and design, gets purposely shortened[1]. This also affects consumers' right to repair [Hernandez et al., 2020]. All this is part of obsolescence, aimed at letting companies make money by selling new products. «Did you know that you don't need a new product until companies decide to instill the need for them?» [Mancini, 2019].

Consumers, on their own, rarely engage in self-reflection upon their behaviours, partially due to the manipulation operated by advertisement campaigns, asking whether a device is truly needed, and this mechanism keeps going. Discarding an EED is easy, as is buying a new one from the vast assortment offered in the shop windows of shopping malls. But do we ever think about the processes which, in the background, often forgotten or completely ignored, have to run to deliver these shining goods whose availability we take for granted? Do we know what they mean from an ecological, social, and environmental perspective [Argabrite et al., 2022]?

1.2 What is Unseen

Consumers, indeed, should carefully reflect upon these processes which, unfolding through space and time, allow us to own a brand new piece of technology [Argabrite et al., 2022]. All of these processes are integral and essential to the tech supply chain, and while some of them continue to over-exploit rare natural resources, often devastating the environment [Dudka & Adriano, 1997, Von der Goltz & Barnwal, 2019], others make use of child work as low-cost labour [Faber et al., 2017]. While this happens before the actual assemblage of the EED, symmetrically the same happens, although in other ways, once the EED is disposed of, with the central phase, the one with the EED employed by the owner, being like a brief and suspended moment in which the device really seems to shine. This means that the EED dismantling chain is no better, with large streams of e-waste reaching developing countries from the wealthy ones, in a trafficking system often blurring the border with legality, with criminal organisations regularly interfering with the process. Once at their destination, with China and Africa as the most eager importers, illegal and uncontrolled dismantling takes place in the majority of the cases [Premalatha et al., 2014]. This activity, known as informal recycling, sees unprotected and untrained workers opening the discarded EED to extract and separate the different components and materials. While these processes are usually carried out by bare hands, common are other rudimental techniques such as acid melting and burning, which release into the air, soil, and water extremely toxic compounds, poisoning the food chain and, eventually, the people [Premalatha et al., 2014]. To give a sense of how spread e-waste trafficking and informal recycling are, according to the UN E-waste Monitor in 2019 53.6 million metric tons (Mt) of e-waste were generated worldwide, of which only 17.4% (9.3 Mt) were formally recycled, while the rest (82.6%, 44.3 Mt) met an uncertain fate [Forti et al., 2020].

A solution to all this seems more complicated than it may appear, as over-production, over-consumerism and (e-)waste over-production are mutually bonded. But also assuming the possibility to change the consumerism model and change people's minds, thus removing one of the engines of this chain, companies have the final word. Since obsolescence and rapid turnover of EED contribute to their profits, it is unlikely, or rare, that they trim their earnings in the name of environmental justice. However, despite the (apparently) hopeless situation, there is to start from somewhere (to try) to change things.

2 Engaging with the Problem

Fortunately, external actors are stepping in and proposing alternative and creative ways and suggestions to increase awareness and, through small and daily actions, mitigate the problem. It is the case with various non-governmental organisations and movements with initiatives such as Repaircafè[2], promot-

[1] https://www.bbc.co.uk/news/technology-63132831

[2] https://www.repaircafe.org/en/

ing knowledge sharing and collaborative repair. What stands out thanks to these initiatives is that the effort of everyone from the most diverse contexts is needed to tackle the e-waste phenomenon and its causes, and the contribution from the artistic field makes no exception. Sound artists and musicians, through the artistic medium, can shed light on the problem also by taking advantage of the longstanding and multifaceted interest music and sound art have in nature and the environment. From the music of Vivaldi, Beethoven and Debussy, to the studies on the soundscape of Raymond Murray Schafer and Barry Truax and the development of the field of acoustic ecology, and to the formalisation of the branch of sound art called ecological sound art, many different experiences are demonstrating this linkage [Gilmurray, 2016, Wrightson, 2000].

2.1 (Circuit) Bending E-waste

Dealing with technology, art, and environmentalism, as a general definition, «Circuit bending primarily focuses on exploring unexpected behaviours of circuits by applying modifications to their electronics.» [Dorigatti & Masu, 2022]. In the artistic domain, circuit bending is used to turn EED into unexpected and unique musical instruments. Discovered by chance by Reed Ghazala [Ghazala, 2004], circuit bending is today an established artistic practice [Hodgson, 2017].

While it is clear how circuit bending connects to technology and art, it might not be how it deals with environmentalism. Firstly, this connection lies in that bent devices do not have to be new but can be recovered amongst the often still functioning and daily discarded ones [Dorigatti & Masu, 2022, Ghazala, 2004, Hertz & Parikka, 2012]. However, the practical side is just a facet of the whole [Goddard, 2015], as it is argued that the real linkage resides in the possibility, through artistically-employed bent devices, to promote awareness and reflection of the audience on the problem of e-waste [Dorigatti & Masu, 2022].

2.2 Interaction as Reaction

Despite this potential, usually, circuit bending is neglected from this perspective. Therefore, it is from this background that this project, Sound Art from Scrap, takes its shape and objectives. On the one hand, it aims to turn discarded EED into repurposed artistic devices to further employ their media output in ecological sound and media art aimed to shed light and awareness on the e-waste problem and its causes. On the other hand, it aims to investigate circuit bending as a practice, exploring, understanding, and testing its overlooked ecological and environmental potential.

To summarise, this project aims to interact with e-waste, circuit bending, and sound art at once to investigate circuit bending at the intersection of its core set of disciplines by fostering the interaction between the ecological-theoretical and practical-artistic sides.

3 Progress and Discussion

This project is mostly stepping into unknown territory as available research on circuit bending does not usually focus on the ecological and theoretical sides and barely explores it beyond the techno-practical and material surface. For this reason, the first step has been to frame and contextualise circuit bending drawing from subjects such as philosophy, ethics, aesthetics, and sustainability. The results showed how broad and complex is the network of relationships linking circuit bending to different disciplines which, beyond its core set of more technical-oriented subjects, «[...] contribute to its contextualization in the contemporary world and society from a different, humanistic perspective.» [Dorigatti & Masu, 2022].

Successively, mainly by drawing from existing literature on sustainable HCI, a set of suggestions have been developed to bring environmental and sustainability instances within the circuit bending practice, thus making it as sustainable as possible. These suggestions, additionally, propose ways to make the audience conscious of such environmental issues when embedded, thus fostering the aforementioned critical reflection and awareness, should bent instruments or their output get employed within the artistic context.

Further planned steps are the perfection and expansion of these suggestions through engaging with the community of benders through workshops and focus groups and their actual implementation in sound art and consequent evaluation. This last step will involve engaging with other artists and with the audience.

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