Skarlatidou, A., Trimm, C., Vitos, M., Haklay, M. (2019): Designing Data Collection Interfaces for Low-literate Users. In: Proceedings of the 17th European Conference on Computer-Supported Cooperative Work: The International Venue on Practice-centred Computing an the Design of Cooperation Technologies - Exploratory Papers, Reports of the European Society for Socially Embedded Technologies (ISSN 2510-2591), DOI: 10.18420/ecscw2019_ep02

Designing Collaborative Data Collection Interfaces for Low-literate Users

Artemis Skarlatidou[1], Caroline Trimm[2], Michalis Vitos[1], Muki Haklay[1]

[1]Department of Geography, University College London; [2]UCL interaction Centre, University College London

a.skarlatidou@ucl.ac.uk, caroline.trimm.15@ucl.ac.uk, michalis.vitos@ucl.ac.uk, m.haklay@ucl.ac.uk

Abstract. Data collection applications on smartphone devices support indigenous communities in developing countries to record and preserve traditional ecological knowledge, collaboratively collect data around issues that are important to them and use these tools to subsequently identify locally-acceptable solutions with global impacts. Development of these interfaces needs to consider users' familiarity with technology as well as their education and literacy levels. This study builds on existing HCI4D research, which is also of interest to the CSCW community, in order to develop and evaluate, for their usability and user preferences, four user interfaces with low-literate people in the UK. Our findings suggest that linear navigation structures and a tangible interface are almost equally usable and preferred when they require minimum interaction with the device. Our preliminary analysis provides a deeper insight into the design issues to inform development of smartphone-based interfaces using various interaction types and we report on our methodological challenges from carrying out HCI research with low-literate people in the UK. The findings of this paper are used to inform the experimental design of additional work that we carry out with low-literate users in Namibia.

Introduction

Western beliefs that techno-scientific innovation, complex legislation, international agreements and top-down approaches can provide the solution and let us live a sustainable future have started slowly to fall apart. This is due to the widely documented disconnect that these strategies have from their actual recipients. Jerome Lewis who works with pygmy hunter-gatherers, explains that "people are integral to how their environments are shaped and the diversity that these environments support" (SynchronicityEarth.org, 2018). Excluding local communities from the broader sustainability debate and agenda not only disconnects us from primary sustainability goals but this further leads into strategies that are doomed to create unsustainable solutions.

For thousands of years people had to rely on their local environments to satisfy basic needs and through time communities have developed significant knowledge to help them deal with local issues. Amongst other types of knowledge, traditional ecological knowledge (TEK), is recognised within indigenous communities for millennia and it started to receive some attention from western knowledge structures and paradigms for its potential to support local and global sustainability. In line with inclusion and the 'leaving no one behind' principles of the UN's 2030 agenda for sustainable development, this requires zooming into local environments and their people to understand how they interact with them. With that aim in mind Extreme Citizen Science (ExCiteS) is a philosophy of

> "situated, bottom up practices which take into account local needs, practices and cultures and which work with broad networks of people in order to design and build new devices as well as knowledge creation processes which can truly transform the world".

Central to this philosophy are collaborative data collection tools, which support individuals and communities in the collection of knowledge they choose to preserve or in the collection of evidence which helps them demonstrate their local issues, an essential requirement in order to subsequently take further action which may have real impacts.

Design and development of data collection tools to support the development and processing of environmental and TEK is not trivial. As previous studies from the context of CSCW have demonstrated these usually rely heavily on collaborative tasks, or tasks which have the potential to bring the community closer together so that such knowledge can be effectively and accurately created (e.g. see Wulf et al., 2011; Pennington et al., 2007; Vitos et al., 2017). Considering that many of these communities are egalitarian, with cases where literally everyone in the community participates in the data collection and the development of community-generated TEK, make the relevance to the field of CSCW even more significant. Studies mainly emphasizing on the mapping interface, when this is used as the main interaction component to support this collaboration, also exist in the field of participatory Geographical Information Systems (PPGIS) (e.g. see Brodnig and Mayor-Schonberger, 2000).

Moreover, with the majority of the communities mentioned above located in developing countries, issues such as technological infrastructure, familiarity with technology, education and literacy, local practices and environmental conditions are of utmost importance in terms of achieving seamless local human-computer interactions. Therefore, designing for these communities also traces back to the field HCI4D which is concerned with similar research questions to inform the development of information and communication technologies (ICT) in developing countries and where there is also a growing interest by the CSCW research community in terms of exploring how to *"bring new technology users from underserved communities into the fray"* (Kumar and Dell, 2018, p.2; Dillahunt et al., 2017). This exploratory paper contributes mainly to the discipline of ICT4D/HCI4D - and given the growing significance of TEK in this context – to the discipline of CSCW; we believe that with our empirical findings and methodological observations we will influence future work in both disciplines, especially with respect to designing for low-literate users.

Our emphasis is on interactions of low-literate users with mobile interfaces. It is expected that by 2025 mobile subscriptions will reach 5.9 billion, with growth mainly driven by developing (GSMA Intelligence, 2018). It therefore comes with no surprise that a growing research body explores mobile phone use (Dell and Kumar, 2016) - mainly basic or feature phones - and especially how low-literate users interact with them, as most mobile devices "assume a reasonable amount of literacy" (Dodson *et al*. 2013, p. 389). Currently, only a few studies examine how low-literate users interact with smartphones - despite their increasing lower costs and smartphone ownership being on the rise (Poushter *et al*. 2018). An even lower number of studies look into the design of interfaces that may assist low-literate users in data collection tasks which may further have the potential to support TEK in a collaborative context. In this paper, we build on methodological challenges discussed in the literature and examine the potential of carrying out an experiment with low-literate people in the UK to investigate the most successful interaction modes in a smartphone environment. Our experimental results will subsequently inform the interface design and additional experiments with end-users in Namibia and other regions in developing countries. We further reflect on our experience from carrying out experimental work for this type of participants in the UK, and we hope that our study will contribute to the evidence that it is being collected and which reports on how we can overcome some of the ICT4D methodological challenges by running usability studies with 'proxy' users in developed countries.

Background

UNESCO defines literacy as the ability of a person to read and write a short simple sentence in his or her everyday (UNESCO, 2006). Medhi et al. (2010) use the term low-literate to refer to: non-literate - i.e. those with an inability to read or write - and semi-literate - i.e. those that are able to read with difficulty. The authors suggest that low-literate people exceed the two billion worldwide. The term 'low-literate' in this study, as it is explained later in this paper, is used to refer to people with limited confidence in completing certain tasks, which assume a certain level of textual literacy in the developed world, and it further extends to include people with low digital literacy skills.

Early research on mobile phones for developing countries, uses ethnography to understand contextual characteristics and user needs (Chipchase, 2006; Belay an McCrickard, 2006; Dodson *et al.* 2013). Studies also carry out prototype development and usability evaluations to test mainly communication features (of basic phones, feature phones and occasionally smartphones) such us the phone's diary to make a call or the use of text-message functionality (Lalji and Good, 2008; Friscira *et al.* 2012; Dodson *et al.* 2013). Given a growing number of mobile phones are now connected to the Internet, research also explores the design of applications for water quality information and alerts (Brown *et al.* 2012); search for a job or navigating the city (Medhi *et al.* 2007) and health applications (Chaudry *et al.* 2012; Kumar and Anderson, 2015).

Although there are still a few studies which suggest augmenting rather than eliminating text-based features in ICTs for low-literate people (Knoche and Huang, 2012), a much higher number of research studies demonstrated that pictorial interfaces with little or no text are more useful (Parikh *et al.* 2003; Medhi *et al.* 2006; Medhi *et al.* 2007). Lack of education and literacy skills do not only influence one's ability to read text, but as Medhi *et al.* (2010) discuss, a person's cognitive abilities and linguistic sequential memory. One of the most notable implications of this is its direct effect in people's ability to understand abstractions, which are now commonly used in interface design and mainly for supporting hierarchical navigation and information structures. An increasing number of studies demonstrate low-literate people's difficulties in understanding and using menus that are based on hierarchies and instead recommend linear structures with up and down button or scrollbars to navigate them (Lalji and Good, 2008; Chaudry *et al.* 2012; Medhi *et al.* 2010; Winchiers-Theophillus *et al.* 2010]. It should be, however, noted that improved digital literacy and familiarity in terms of interacting with mobiles phones helps low-literate users overcome this problem and slowly develop similar proficiency levels in using their phones with those of literate users (Medhi *et al.* 2010).

Research further suggests that pictorial design should be fully embedded into cultural contexts, local meanings (Lalji and Good, 2008; Medhi *et al.* 2006) and user preferences (Lalji and Good, 2008; Frommberger and Waidyanatha, 2017). There is evidence in the literature that low-literate users understand better hand-drawn, semi-abstracted graphics which incorporate action cues, while photo-realistic images are usually more effective in deeper interaction modes (Medhi *et al.* 2006). Additional modalities in the user interface such as audio feedback and voice annotation have been also tested and proved to be effective in specific contexts of use (Chipchase, 2006; Medhi *et al.* 2006; Deo *et al.* 2004; Medhi *et al.* 2007; Lalji and Good, 2008).

Previous research around input methods for basic or feature phones explores the use of keypad (Bailly *et al.* 2014; Lalji and Good, 2008) while few more recent studies investigating interactions with touchscreens (Chaudry *et al.* 2012; Friscira *et al.* 2012). Depending on the context of these studies and whether participants own a smartphone or not, there is consensus that low-literate users are hesitant with touching the screen of touchscreen devices and they are struggling with different types and outcomes of tapping. Friscira *et al.* (2012) suggest that low-literate participants should be first trained to the basics of smartphone touchscreen interaction. Despite these concerns, Chaudry *et al.* (2012) suggest the use of scrollbars on touchscreen, while Katre (2008) argued that low-literate users' lack of fine motor skills due to non-practice in writing makes thumb-based interaction more effective.

Although less popular compared to research around communication features, technologies (mainly PDAs and mobile phones) which are used to support low-literate users in data collection tasks have been around for some time (Vitos *et al.* 2013; Lewis and Nelson, 2006). Participatory mapping is a well-established methodology for obtaining knowledge from local communities concerning their living conditions and their environment. However, our focus here is on ICT technologies that could be used by the communities themselves, whereas in traditional participatory mapping exercises in this context, the documenting of resources and map-making was produced by expert cartographers with the communities' active assistance (Vitos, 2018). Examples from our context include: CyberTracker, a pictorial data collection interface, which has been used by non-literate trackers mainly in South Africa to support wildlife monitoring and natural resource management (Leibenberg *et al.* 2017); a smartphone-based app to collect georeferenced document and upload information that can support campaigns against illegal logging activities in Cambodia (Copenhagen Post, 2017); Extreme Citizen Science tool Sapelli, a pictorial smartphone-based interface which allows non-literate indigenous communities in Congo, Brazil, Cameroon, Namibia and others to collect any data that supports indigenous communities in knowledge co-production practices and which is used by non-literate (Vitos *et al.* 2017); the Sahana Disaster Management system that employs pictorial icons to check the emergency preparedness of low-literate communities in Philippines and provide them with response and recovery information (Frommberger and Waidyanatha, 2017).

HCI research in this context is limited, with the majority of experiences remaining mostly anecdotal evidence; few of these experiences were presented in the Workshop on 'Lessons learned from volunteers' interactions with Geographic Citizen Science' which took place in London in April 2018 and which was organized by this paper's authors. The few existing findings are not different from the research discussed above. For example, Vitos *et al*. (2017) report that symbolic metaphorical conventions to represent categories in pictorial design do not work with low-literate people despite those being developed in participatory design workshops (**Figure 1**). Icons to represent specific objects had to incorporate action as they were taken too literally and therefore agree with (Medhi *et al*. 2006). Fear of using the technology and difficulties with the touchscreen, due to rough skin, or not understanding input methods (e.g. tapping and long clicks) have been also observed (Vitos *et al*. 2017; Vitos, 2018).

Figure 1:Community workshop for participatory pictorial design in Congo – Extreme Citizen Science project.

Evaluation of Sapelli, a data collection application which is based on a hierarchical navigation structure, is in line with previous research findings as low-literate people had difficulty understanding how to navigate it (Vitos *et al*. 2017). A physical interface was developed and evaluated to overcome Sapelli's challenges in the field; Tap&Map is a smartphone-based interface which uses near field communication (NFC) cards to tag an object together with each GPS coordinates (Vitos *et al*. 2017). Results demonstrated that participants had a 97.5% success rate in task completion using Tap&Map and they found it "faster, easier and more comfortable to use compared to Sapelli" (Vitos *et al*. 2017, p. 1584).

In this paper we consider research findings from the broader ICT4D field and previous work with Sapelli and Tap&Map to develop and further evaluate four user interfaces for data collection purposes with low-literate participants in the UK, which have the potential to further assist low-literate users in developing countries to perform collaborative tasks. For example, our findings will support the development of interfaces to collaboratively collect resource management data or data related to TEK, which is usually an important consideration with indigenous communities, so that the communities themselves can collaboratively identify solutions to local issues (e.g., wildlife crime in Cameroon, illegal logging in the Republic of Congo, resource management and fighting cattle invasions in Namibian Nyae Nyae Conservancy). It should be finally noted that although audio found to improve usability of otherwise problematic hierarchical structures (Vitos *et al.* 2017) we haven't explored this feature further, as it is not always an appropriate modality especially in high risk environments in terms of people's safety (e.g. when monitoring wildlife crime).

Aims and Study Design

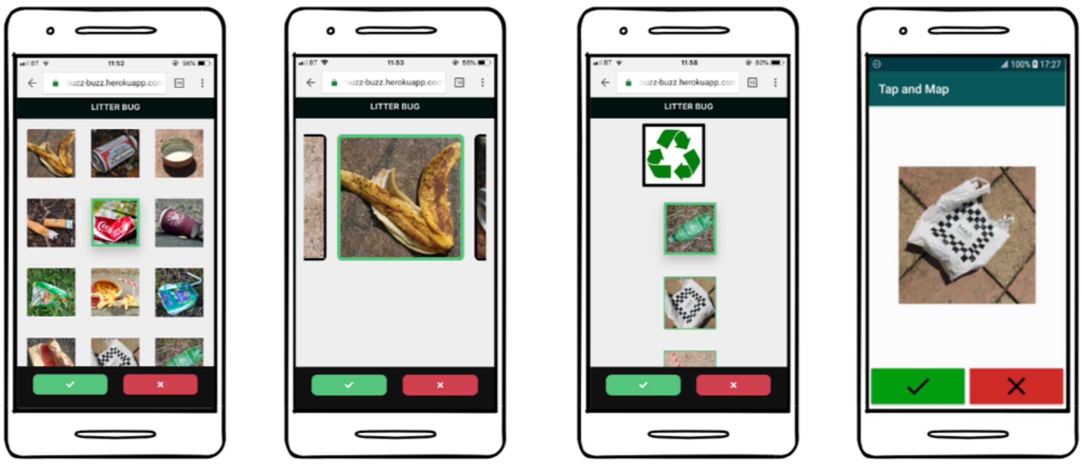
Aims and Context

In this study we carried out a controlled experiment to evaluate four alternative user interfaces on a smartphone device, which have the potential to support low-literate users in data collection. Our goals are to evaluate: a. which interface is the easiest to use for the target user group and; b. which interfaces the users prefer to use.

One of the most widely recognised methodological implications in HCI4D research, is the difficulty in carrying out experimental work in remote locations, especially as part of an agile UCD approach. To make preliminary design choices which we could then test with users in developing regions we decided to explore how a representative user audience based in the UK, interacts with different interfaces. Within this context our first experimental design implication was to create a recognizable and meaningful task for our participants; a task preferably from the environmental context, which they could understand quickly, and which would involve the use of pictorial icons that they could immediately recognize and relate to them. Litter data collection is a task that we expected to appeal and be sensible to our participants and therefore it was the topic chosen for our experiment. Our research started with the design of initially 20 litter images (e.g. banana peels, cola cans, plastic carrier bags), which after a pilot study with five participants, were reduced down to 15 in order to remove unnecessary complexity which was overwhelming for our subjects and to further decrease the time required to run the experiment from six minutes to four minutes per task. Three images were also deemed unclear during the pilot and therefore they were replaced, while the size of all images increased so they were easier to see upon recommendation of our pilot participants.

In the same pilot study we further tested that tasks and supporting materials were easy to understand. Although, we initially included a combination of icons and images to investigate user preference over different visualisations this combination found to be confusing. Despite the fact that previous research with low-literate users in developing countries suggests the use of hand-drawn, semi-abstracted images (Medhi et a., 2006) we decided to include only photo-realistic images, as we are aware of previous research in data collection with low-literate users in urban centers which suggests the use of photo-realism perhaps due to the fact that people in urban centres are more exposed to similar visual cues (Chiaravalloti, 2018).

The four interfaces that we evaluated in our study are shown in **Figure 2** and include: Icon Menu (Figure 2a); Swipe Menu (Figure 2b); Sapelli Menu (Figure 2c); Tap&Map (Figure 2d).



a. Icon menu b. Swipe menu c. Sapelli-inspired menu d. Tap&Map

Figure 2: Data Collection Interfaces tested in our study

The first two interfaces (i.e. Icon and Swipe menu) were designed to provide a provide a linear navigation structure (i.e. a structure which is not based in a hierarchy; it supports moving backward or forward in a sequence of objects) as previously suggested (Brumby and Zhuang, 2015; Cockburn *et al*. 2007; Lalji and Good, 2008; Chaudry *et al*. 2012; Medhi *et al*. 2010; Winchiers-Theophillus *et al*. 2010). The Icon menu showed a total of 12 images in two screens (i.e. three per each row) and required a single finger scrolling to navigate vertically between the two screens. The Swipe menu included the same images which were shown horizontally, with one image shown per screen. Main interaction input was a horizontal single finger swiping (either left or right) to navigate across the images.

The Sapelli menu and Tap&Map interfaces were designed based on previous work on data collection with low-literate users (Vitos *et al.* 2017). Sapelli, provides a hierarchical menu structure which in our study had two top level categories for grouping the 15 litter items in recyclable and non-recyclable. Sapelli requires users to tap to select an image but it also requires them to correctly identify to which of the two categories the item falls and therefore navigate across this hierarchical menu structure. Tap&Map (Vitos *et al.* 2017) is a tangible interface and it requires very little interaction with the phone. The data items are shown on 15 physical NFC cards (i.e. one per each image). Participants browse the cards and once they identify the one they want to map, they tap the card against the phone and the image appears on the phone. Participants have to further confirm their selection by tapping the tick or cross icon on the phone (as shown on Figure 2d) which is the only interaction with the screen of this interface.

Experimental Design

Starting with a 15 minutes training session each participant was introduced to the basics of smartphone interaction, using each one of the four interfaces and the experiment's instructions and they were provided with either a Motorola Moto G or Samsung Galaxy Xcover 4 device, which they used to complete the tasks. The experiment required participants to complete a goal-oriented task using each of the four interfaces by matching the image on the interface with the appropriate litter type (i.e. total tasks n=4). To ensure that all litter types were equally used (rather than picking from those only physically present on a street), the 15 litter types were all shown as separate A4 paper printouts which were placed around participants before the experiment. Each task then required participants to map as many litter images as possible (out of total n=15) in 4 minutes using each of the four interfaces. A 'within subjects' design required all participants to complete the same tasks using all four interfaces and the interfaces were shown in a randomized order. Each experiment was carried by one of this paper's authors.

Task completion times and error rates were measured during the test using a timer (i.e., to measure the four minutes task duration) and observation notes (e.g.., an error occurred when a participant matched an icon to the incorrect A paper printout which was noted by the researcher observing the experiment). At the end of the experiment a score was calculated by summing each participant's number of correct matches and deducting the number of mistakes (i.e. Task Success = Total number of correct matches - Number mistakes). These scores were then averaged to provide an overall score for each interface. At the end of each one of the four tasks participants were verbally asked how they found the task, how confident they felt completing the task and how much they enjoyed this version of the litter data collection application. These questions were consistently asked across all tasks and all participants to understand their subjective experience of using each interface. At the end of the experiment participants were again verbally asked which of the four interfaces they most and least enjoyed; the researcher conducting the experiments took notes of their answers which were then processed in the analysis. The experiments were also audio-recorded, data were transcribed and further analysed. Quotes from participants and research observations were amassed in addition to quantitative data to provide some qualitative insight. The data was used to produce a selection of pivot tables in Microsoft Excel to give a high-level overview of how each interface performed. This made it possible to detect trends and anomalies in the data. Individual quotes and observations were grouped into a number of themes that were analysed and turned into key findings.

Recruitment and Participants

Recruiting participants with low-literacy skills in the UK was a complex process. Within a period of over two months we contacted 50 organizations in the UK including adult learning centres, adult literacy learning groups, job centres, churches, community centres, local radio stations and so on. It is not uncommon for illiterate people to hide their lack of literacy and this is another obstacle HCI4D research which takes place in a western country has to overcome (Friscira *et al*. 2012; Knoche and Huang, 2012). To work around this problem we were slightly more flexible in terms of how the term 'low-literacy' is used in the HCI4D literature, to include people who were able to read or write a short message but with limited confidence in basic skills for life (as described by the UK Government 2011 Skills for Life Survey) and which assume a certain level of literacy (see also Kodagoda and Wong, 2008).

Prior to the experiment participants were asked questions to establish their age, gender, ethnicity, occupation, level of literacy and numeracy using the UK Government 2011 Skills for Life Survey (Department for Business, Innovation and Skills, 2012) and participants' confidence with technology using the Open University Digital Skills Checklist (The Open University, 2018).

Overall 13 participants took part in the experiment with an age range of 58-80 years old (avg=71; females=7; males=6); participants from this age group were less confident in their interactions with mobile phones (especially smartphones), which is usually a common characteristic in the indigenous communities we work with in remote areas. Two of the participants were completely illiterate; none of the participants were confident in using technology although 12 out of 13 owned a phone but mainly for phone calls and/or texting. Our low-literate participants (n=11) were confident writing a short physical message to friends and describing their medical symptoms to a physician but they were not confident withdrawing cash from an ATM cashpoint, reading a bus timetable and comparing products or services. These tasks assume a certain level of literacy, which in some situations is taken as granted for completing every day tasks and in terms of interacting with digital technologies in the western world. A failure to show appropriate confidence levels and an ability to complete these tasks was a precondition for participant recruitment.

Results

As **Table 1** shows participants scored the lowest with Sapelli (TS=7.1), the highest when using the Icons menu (TS=10.7) followed by Tap&Map (TS=10.2) and the Swipe menu (TS=8.4). Participants commented on the usability of both the Icon menu (e.g. "I like seeing all the pictures together, that made it easy to use" - participant comment) and the Tap&Map interface (e.g. "…this was easy to use, the cards made it easy" - participant comment). Although Sapelli was used in this experiment with only two top level categories its hierarchical structure still confused participants. For example, one participant explained that "this was the hardest [interface to use] as you had to decide whether something was recyclable or not before finding it on the screen".

Table 1: Task Success [TS], Error Rates [ER], Standard Deviation [SD] and user preferences for each interface

	[TS]	[ER] (%)	Standard Deviation [SD]	Most Liked overall	Least Liked overall
Icon Menu	10.7	9.4	4.8	2	1
Swipe Menu	8.4	4.2	4.2	0	8
Sapelli	7.1	2.5	3.09	1	3
Tap&Map	10.2	2	3.3	10	1

Although our population sample is small to draw any concrete conclusions to link results to user demographics, we further observed that participants who had no prior experience in using a smartphone performed better using Tap&Map (TS=8.0), followed by the Icon Menu (TS=6.6), the Swipe menu (TS=4.8) and finally Sapelli (TS=4.0).

Although the Icon menu scored the highest in terms of task success, it was also the interface where we observed most errors taking place. However, participants managed to recover easily from their errors and hence complete their tasks successfully. We believe that it was the interface's usability that paradoxically led users to make more errors since the observer noticed that users became overconfident and rushing through the task when using the Icon menu. In terms of error rates Tap&Map was the most successful, with a 2% error rate, followed by Sapelli (ER=2.5%) and the Swipe menu. (ER=4.2%).

Ten of the thirteen participants liked the Tap&Map interface the most. The one participant who disliked Tap&Map had arthritis, which caused a lack of dexterity in his hands and therefore difficulty in handling the NFC cards. Interestingly enough the least liked interface was the Swipe menu; during the experiment participants observed to struggle with the one finger swiping interaction which caused frustration to some (e.g. "this one [Swipe menu] didn't adapt to me, it wasn't easy and it was quite frustrating" – participant comment).

We also asked participants at the end of each task to rate each interface in terms of its perceived usability, how confident they felt completing the task and how much they enjoyed using it using a four-likert scale. Tap&Map and the Icon menu scored the highest in terms of perceived usability and confidence, followed by Sapelli and the Swipe menu. Participant 13 who was illiterate and had never held a smartphone before commented about Tap&Map "I could do that all day, I am used to not being able to do anything on a phone, maybe I am not that thick after all…this gives me a lot of confidence that I am not as thick as I think I am".

At the end of the experiment, once participants had experienced all four interfaces, they were asked which interface they most and least liked using. The Swipe menu was the interface our participants liked using the least (8/13) while Tap&Map was the interface participants liked using the most (10/13). Three participants did not particlarly enjoy using Tap&Map, with two participants preferring to use the Icon menu (2/13). These three participants who did not enjoy using Tap&Map experienced some physical discomfort while using Tap&Map which was not surprising due to the age of the participants – and led to their lack of enjoyment.

Discussion and conclusions

Building strong sustainability agendas which have the potential to truly impact and transform our world, amongst others, requires zooming into local environments and providing the mechanisms that let people look into issues they face locally, and supporting them in the identification of effective solutions to address them. Data collection tools are becoming increasingly popular in terms of supporting users with these endeavors. Low-literacy and the limited prior experience of users in interacting with technological artefacts need to be taken into account when designing for these particular user audiences. Taking into account existing HCI4D literature in this study we developed and evaluated four alternative interfaces to support low-literate users in data collection tasks using smartphone devices.

Building on research we suggests that a linear navigation structure works well with low-literate users, we developed two interfaces which had a linear navigation but required different types of interaction. We found that a linear navigation, which involves minimum interaction with the smartphone, was the most successful interface (i.e. Icon Menu) in this study, for its usability and the second most preferred by our participants. We also observed that a linear structure can result in a very negative user experience and reduce usability when users are expected to constantly interact with their device, as it was the case with the Swipe menu, which was although achieved a higher score success rate than Sapelli it was the least like interface. It should be noted that there are no other studies to report a negative user experience associated with linear navigation structures and therefore this finding might need further investigation in other contexts of interacting with smartphone devices.

The second most successful interface in terms of task success was Tap&Map, which scored the highest for user preference. Tangible interfaces have the potential to keep interaction with the phone at its minimum and this was appreciated by the majority of our participants. It should not be, however, noted that the average age of our participants was 70.9 years old and some of them suffered from arthritis, which caused difficulty navigating across the pack of the NFC cards, therefore we suggest that further testing is required to assess how usable are tangible interfaces for data collection purposes in various environmental conditions and for various user groups.

There is already evidence in previous research both from the context of data collection but also mobile phone use in a broader sense, that hierarchical structures are problematic with low-literate users, and our results agree with those findings. Although Sapelli scored the second lowest error rate, it was still the least usable interface in terms of its task success rate. This highlights the importance of another usability principle, error recovery, which is much more problematic in hierarchical navigation structures since users once they get into the lowest levels of a decision tree find it harder to go back and recover from any errors compared to recovering from an error in a linear navigation structure (e.g. the Icon menu had the highest error rate, yet it was the most usable interface in terms of task success). From this finding we suggest that future research related to hierarchical navigation structures should look into error recovery and interface design cues that have the potential to release users from the already increased cognitive effort that hierarchical structures require. Such features could have a significant impact when a hierarchical navigation structure is the only option.

HCI4D researchers explain how conducting HCI research in developing countries has unique challenges due to sociocultural, linguistic and other implications (Anokwa *et al*. 2019; Chetty and Grinter, 2007). One major obstacle to implementing a user-centred design approach to support the development of extreme citizen science data collection tools is proximity and access to the target user audiences. In other words, constant development and evaluation of prototypes with target users in the field is not always feasible neither it is possible to carry out complex experimental designs which rely on evaluating a high number of prototypes in one go. At the same time running usability studies in a western country which require the recruitment of low-literate (or even proxy) users has its own challenges and still results may be biased as they are open to influences from local socio-cultural and environmental conditions which are significantly different from those in the field. In an attempt to deal with all these challenges, we tested four prototypes with a relevant participant audience in the UK. Although it may be argued that this study's population sample is small to run an in-depth analysis and provide concrete conclusions, it has provided us with enough insight in terms of choosing the two most successful interfaces which we then tested with low-literate users in Namibia for collecting data for natural resource management purposes. Our preliminary findings from the field testing agree with the usability study that we describe in this paper. To further evaluate the validity of this approach, we are planning to incorporate more testing of our interfaces and tools in developed countries with representative user audiences, in preparation of and prior to testing in remote locations, as others have also recommended (e.g.Chetty and Grinter, 2007; Knoche and Huang, 2012). We believe that providing evidence and reflecting on the results and effectiveness of these experimental approaches may significantly help tackle some of the most critical methodological challenges in HCI4D research.

ACKNOWLEDGMENTS

We would like to thank the Extreme Citizen Science research team for their input in this study's experimental design and the people who participated in our study. This research project is funded by European Research Council's project Extreme Citizen Science: Analysis and Visualisation under Grant Agreement No 694767.

REFERENCES

Anokwa, Y. et al. (2019). 'Stories from the field: Reflections on HCI4D Experiences'. *Information Technologies and International Development*, vol. 5, pp. 101-115.

Bailly, G., Oulasvirta, A., Brumby, D., Howes, A. (2014). Model of visual search and selection time in linear menus. In Proceedings of the SIGCHI Conference on human factors in computing systems, (Toronto, Canada), pp. 3865-3874.

Belay, E. and McCrickard, S. (2006). 'Mobile User Interaction Development for Low-Literacy Trends and Recurrent Design Problems: A Perspective from Designers in Developing Country'. *Mobile User Interaction Development*, pp. 409-417.

Brodnig, G., Mayer-Schönberger, V. (2000). Bridging the Gap: The Role of Spatial Information Technologies in the Integration of Traditional Environmental Knowledge and Western Science. The Electronic Journal of Information Systems in Developing Countries, vo. 1, no. 1, p. 1-15.

Brown, D., Marsden, G., Rivett, U. (2012). Water Alert!: Using Mobile phones to Improve Community Perspective on Drinking Water Quality in South Africa, In Proceedings of the 5th International Conference of Information and Communication Technologies and Development, Atlanta, USA, pp. 230-240.

Brumby, D., Zhuang, S. (2015). Visual grouping in menu interfaces. In Proceedings of the 33rd Annual ACM Conference on human factors in computing systems, Seoul, Korea, pp. 4203-4206.

Chaudry, B., Connelly, K., Siek, K.,Welch, J. (2012). Mobile interface design for low-literacy populations. In Proceedings of the 2nd ACM SIGHIT International Health Informatics Symposium: pp. 91-100.

Chetty, M., Grinter, R. (2007). HCI4D: HCI challenges in the global south. In CHI '07 extended abstracts on Human factors in computing systems, San Jose, USA, pp. 2327–2332.

Chiaravalloti, R. (2017). Local communities and conservation in the Pantanal wetland, Brazil. *Doctoral dissertation. University College London*, London, UK.

Chipchase, J. (2006). 'How Do You Manage Your Contacts If You Can't Read or Write? Interactions'. *Interactions,* vol. 13, no. 6, pp. 16-17.

Cockburn, A., Gutwin, C., Greenberg, S. (2007). A predictive model of menu performance. In Proceedings of the SIGCHI Conference on human factors in computing systems, San Jose, USA, pp. 627-636.

Copenhagen Post. (2017). Danish app helping Cambodian activists to combat illegal deforestation. http://cphpost.dk/news/danish-app-helping-cambodian-activists-to-combat-illegal-deforestation.html (Accessed 15 April 2018).

Dell, N., Kumar, N. (2016). The Ins and Outs of HCI for Development. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, San Jose, USA, pp. 2220-2232.

Deo, S., Nichols, D., Cunningham, S., Witten, I., Trujillo, M. (2004). Digital library access for illiterate users. In Proceedings 2004 International Research Conference on Innovations in Information Technology (IIT2004,) Dubai, pp. 506–516.

Department for Business, Innovation and Skills. (2012). The 2011 Skills for Life Survey: A Survey of Literacy, Numeracy and ICT Levels in England. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/36000/12-p168-2011-skills-for-life-survey.pdf#page=66 (Accessed 1 June 2018).

Dodson, L., Sterling, R., Bennett, J. (2013). Minding the Gaps: Cultural, Technical and Gender-based barriers to mobile use in oral-language Berber communities in Morocco. In Proceedings of the Sixth International Conference on Information and Communication Technologies and Development, Cape Town, South Africa, pp. 79-88.

Dillahunt, T., Erete, S., Galusca, R., Israni, A., Nacu, D., Sengers, P. (2017). Reflections on Design Methods for Underserved Communities. CSCW '17 Companion, February 25 - March 01, 2017, Portland, OR, USA ACM 978-1-4503-4688-7/17/02.

Friscira, E., Knoche, H., Huang, J. (2012). Getting in touch with text: Designing a mobile phone application for illiterate users to harness SMS. In Proceedings of the 2nd ACM Symposium on Computing for Development, Atlanta, USA.

SynchronicityEarth.org, 2018. Embracing biological and cultural diversity: An Interview with Dr Jerome Lewis. Synchronicity Earth. (2018). https://www.synchronicityearth.org/embracing-biological-and-cultural-diversity-an-interview-with-dr-jerome-lewis/ (Accessed 2018-09-11).

Frommberger, L. and Waidyanatha, N. (2017). Pictographs in Disaster Communication for Linguistically Challenged and Illiterate Populations: A Survey on Background and Existing Practices. *International Journal of Information Systems for Crisis Response and Management*, vol. 9, no. 2, pp.37-57.

Katre, D. (2008). One-handed thumb use on smart phones by semi-literate and illiterate users in India: A usability report with design improvements for precision and ease. In Workshop on Cultural Usability and Human Work Interaction Design - NordiCHI Conference, Lund, Sweden, 2008.

Kodagoda, N. and Wong, W. (2008). Effects of Low and High Literacy on User Performance in Information Search and Retrieval. In Proceedings BCS-CHI-08 People and Computers: Culture, Creativity, Interaction - Volume 1, pp. 173-181.

Knoche, H., Huang, J. (2012). Text is not the enemy: How illiterates' use their mobile phones. In Proceedings of the CHI Conference on Human Factors in Computing Systems, Auston, USA.

Kumar, N., Anderson, R. (2015). Mobile Phones for Maternal Health in Rural India. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, April 18-23, Seoul. Korea, pp. 427-436.

Kumar, N and Dell, N. (2018). Towards Informed Practice in HCI for Development. In Proceedings of the ACM on Human-Computer Interaction, Vol. 2, CSCW, Article 99 (November 2018). ACM, New York, NY. 1-20.

Lalji, Z., Good. J. (2008). 'Designing new technologies for illiterate populations: A study in mobile phone interface design'. *Interacting with Computers,* vol. 20, no. 6, pp. 574-586.

Leibenberg, L., Steventon, J., Brahman, !N., Benadie, K., Minye, J., Langwane, H., Xhukwe, Q. (2017). 'Smartphone Icon User Interface design for non-literate trackers and its implications for an inclusive citizen science'. *Biological Conversation*, vol. 208, pp. 155-162.

Lewis, J., Teodyl, N. (2012). Accessible technologies and FPIC: independent monitoring with forest communities in Cameroon. In Participatory Learning and Action 65. Ed. by Krystyna Swiderska, Kanchi Kohli, Harry Jonas, Holly Shrumm, Wim Hiemstra and Maria Julia Oliva. Participatory Learning and Action 65. IIED. Chap. 13, pp. 151–165. ISBN: 978-1-84369-851-7

Lewis, J., Nelson, J. (2006). Logging in the Congo Basin: What Hope for Indigenous Peoples' Resources and their Environments? In International Work Group for Indigenous Affairs (IWGIA). Vol. 4, no. 06, pp. 8–15.

Medhi, I., Sagar A., Toyama K. (2006). 'Text-Free User Interfaces for Illiterate and Semi-Literate Users'. *Information and Communication Technologies and Development*, vol. 4, no. 1, pp. 37-50.

Medhi, I., Prasad, A. and Toyama K. (2007). Optimal audio- visual representations for illiterate users. In Proceedings of the 16th international conference on World Wide, (Alberta, Canada), pp. 873-882.

Medhi, I., Gautama, S., Toyama, K. (2009). A comparison of mobile money-transfer UIs for non-literate and semi-literate users. In Proceedings of the SIGCHI Conference on human factors in computing systems, (Boston, USA), pp. 1741-1750.

Medhi, I., Raghu Menon, S., Cutrell, E.,Toyama, K. (2010.) Beyond Strict Illiteracy: Abstracted learning among low literacy. In Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development, (London, UK), 1-9.

Parikh, T., Ghosh K., Chavan, A. (2003). Design Considerations for a Financial Management System for Rural, Semi-literate Users. In Proceedings of Human Factors in computing Systems, (Florida, USA), pp. 824-825.

Pennington, D.D., Madin, J., Villa, F., & Athanasiadis, I.N. (2007). Computer-supported collaborative knowledge modeling in ecology. Workshop on social and collaborative construc- tion of structured knowledge. In *16th International World Wide Web Conference (WWW2007). CEUR Workshop Proceedings, 273.* BANFF, Canada published online.

Poushter, J., Bishop, C., Chwe, H. (2018). Smartphone ownership on the rise in emerging economies. http://www.pewglobal.org/2018/06/19/2-smartphone-ownership-on-the-rise-in-emerging-economies/ (Accessed 09 Sept. 2018).

GSMA Intelligence. The Mobile Economy: Sub Saharan Africa (2018). https://www.gsma.com/mobileeconomy/sub-saharan-africa-2017/ (Accessed 30 March 2018).

The Open University, 2018. Being digital: Digital literacy skills checklist. Available from: http://www.open.ac.uk/libraryservices/beingdigital/accessible/accessible-pdf-35-self-assessment-checklist.pdf (Accessed June 2018).

UNESCO (2006). Chapter 6 understandings of Literacy. http://www.unesco.org/education/GMR2006/full/chapt6_eng.pdf (Accessed 9 Sept. 2018).

Vitos, M. (2018). Making local knowledge matter: Exploring the appropriateness of pictorial decision trees as interaction style for non-literate communities to capture their traditional ecological knowledge. *Doctoral dissertation. University College London*, London, UK.

Vitos, M., Stevens, M., Lewis, J., Haklay, M. (2013). Making local knowledge matter. In Proceedings of the 3rd ACM Symposium on Computing for Development - ACM DEV '13. New York, New York, p. 1.

Vitos, M., Altenbuchner, J., Stevens, M., Conquest, G., Lewis, J., Haklay, M. (2017). Supporting Collaboration with Non-Literate Forest Communities in the Congo-Basin. In CSCW '17 Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing. (New York, USA), pp. 1576-1590.

Winchiers-Theophillus, H., Bidwell, N., Blake, E., Kapuire, G., Rehm, M. (2010). Merging experiences and perspectives in the complexity of cross-cultural design. In Proceedings of the 9th International Workshop on Internationalization of Products and Systems, London, UK, pp. 131-140.

Wulf, V., Rohde, M., Pipek, V., Stevens, G. (2011). Engaging with Practices: Design Case Studies as a Research Framework in CSCW. CSCW 2011, March 19 23, 2011, Hangzhou, China.