Influences of a key on soundwalk exploration with a textile sonic map

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ABSTRACT

Sonic maps are an increasingly popular form of exploring soundscapes, and are a possible means of communicating the experience of a soundwalk. We describe how a printed key influenced exploration of an interactive textile sonic map. We explain the technology behind the map, employing capacitive sensing and real-time audio processing. The sonic map contained 18 binaural recordings extracted from a soundwalk. Thirty participants explored the map. The strengths and limitations of the interfaces were established, and participants' modes of exploration were identified. Results show how the use of the key map levelled the location preference. The participants' experience with the interface suggested possible uses of e-textiles for soundscape awareness promotion and studies, and in the field of interactive audio.

1 Introduction

The term *soundscape* was first used as the sonic analogy of landscape [1], later defined as the human perceptions of the acoustic environment of a place [2]. Perception of soundscapes is studied to explain auditory cognition [3, 4, 5] and to improve urban design [6]. Soundscapes are also researched to enhance creative discoveries [7]. Principal dimensions of soundscape appraisal depend on how pleasant and eventful these appear to the listener [8, 9, 10]. Moreover, judgements are affected by the users' reasons to be in a certain place [11, 12], and whether the soundscape is perceived as appropriate for the function that the space should fulfill [13].
Walking while listening to the surrounding soundscape, or *soundwalking* [14], allows to study soundscapes in their original context. In a previous study, we looked at in situ elicitation of sonic textures as an additional exercise to be completed during a soundwalk [15]. Subsequently we decided to test whether the spaces evaluated during the soundwalk could be experienced and researched without being present in the locations. With the intent of addressing soundscape research themes related to acoustic education, we adopted a creative approach, aiming at intuitiveness. Therefore, we designed a textile interactive sonic map, called Aural Fabric [16], to be able to resonate with designers of spaces and communicate with the general public. The embroidered reliefs on the Aural Fabric invite users to touch the locations encountered during the soundwalk and listen to the immersive recordings of the different ambiances.
Multimodal maps help studying the effect of additional information, such as auditory or tactile, on the cognitive spatial processes related to navigation [17]. Tactile maps help delivering direct spatial information through

design features such as raised lines. Thus, they are often used to investigate the non-visual aspect related to navigation, or as a way-finding tool for visually impaired people [18, 19]. However, interactive audio maps are often designed for touch screens employing haptic feedback, and literature lacks of examples of textile maps conveying sonic ambiences from geographic locations.

Preliminary observations on the use of the Aural Fabric in public contexts suggested that the visual language was appealing and self-explanatory for certain locations, but could be integrated by the aid of a key for a more comprehensive exploration of the artefact. Map keys, or legends, define a visual language used by mapmakers to convey information, such as symbols, their variables, and interpretation keys [20].

In this paper, we examine how a map key supporting the exploration affected the interaction with the Aural Fabric in a laboratory experiment. An overview of the making process and experimental conditions is presented in the Method section. The Results section analyses the interaction data for the entire group of participants and the differences between those with or without a key. We conclude by comparing related work with our findings and suggesting design improvements.

2 Method

Documentation on the design process for the interface used, called *Aural Fabric: Greenwich*, is available on the web[1]. The interface implements 18 sensitive areas unevenly spread across a rectangle of 360mm X 200mm as shown in Fig.2. It consists of an embroidered representation of the top view of the area of Maritime and Historical Greenwich, London. The map shows the buildings and other areas where the recordings took place. Buildings are embroidered in plain conductive thread, whilst greens, courtyards, and the river in conductive and coloured thread with different textures. Non-interactive areas are uniformly embroidered with grey thread, as shown in Fig.1. The top and bottom surfaces are separated by an insulating pad with some holes, in correspondence with the sensitive areas on the top. The bottom layer consists of an embroidered conductive thread circuit reaching two capacitive boards. The boards detect the touch interaction, activating the streaming of the recordings from a Bela
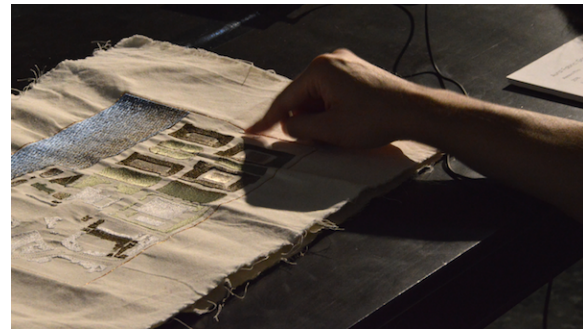

Fig. 1: Example interaction with the Aural Fabric.

computer[2] connected to headphones.

The field recordings used in the fabric were extracted from a 75 minute soundwalk captured from a pair of DPA4060 microphones worn next to the ear canal by a sound artist, wearing also a windscreen, and a pair worn by 3DIO dummy ears held on a stick by the first author leading the walk, not wearing a windscreen. They were selected according to the quality of the content (e.g. no wind, richness of spatial detail) in accordance with another experienced listener, and reduced to 30 seconds, as in other studies [8]. Table 1 shows a summary of the content of the 18 excerpts and their abbreviations. The excerpts are available on the web[3].
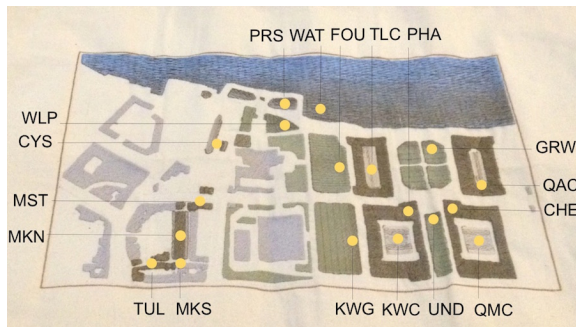
2.1 Procedure

Postgraduate researchers aged between 25 and 43 took part voluntarily in an experiment consisting of exploring the Aural Fabric for 5 minutes with their hands. Experiment sessions lasted 20 minutes, to avoid fatigue in judgments [21]. Sessions included information and ethics forms, background questions, exploration of the fabric, and a post-test questionnaire. Participants could comment aloud while answering the final Likert-scale questions. Where available, comments were recorded to provide qualitative feedback about the interaction with the sonic map. The experiment was delivered in an insulated room or quiet settings without visual distraction, through noise canceling headphones.

2.2 Conditions

Participants were divided in three groups of 10 individuals each, 4 females and 6 males. During the exploration

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[1] http://auralcharacter.wordpress.com/aural-fabric/

[2] http:bela.io

[3] https://soundcloud.com/auralchar

Fig. 2: The Aural Fabric and the correspondent locations, abbreviated.

Fig. 3: Experimental setup.

Abbr.	Location	dominant sounds
TUL	Turnpin Lane	helicopter
MKS	Market South	distant voices
MKN	Market North	voices
MST	Market Street	bus, stop light
CYS	Cutty Sark	voices, birds
WAT	Water (River Thames)	distant boats, water
PRS	Greenwich Piers	boats
WLP	Water Listening	distant sounds, birds
GRW	Green Waterside	footsteps
QAC	Queen Anne Court	gravelly footsteps, voices
QMC	Queen Mary Court	quiet, ventilator, echoey
CHE	Chapel Entrance	whistling, footsteps
UND	Undercroft	clothes hangers, footsteps
PHA	Painted Hall	echoey sounds, whistling
KWC	King William Court	quiet
KWG	King William Green	footsteps, distant traffic
TLC	Trinity Conserv. K.C.C.	music
FOU	Fountain	water, footsteps

Table 1: Abbreviations for the locations and content of the selected excerpts, in soundwalk order.

of the Aural Fabric, the group with the key (KM) could look at an A4 picture showing the optimal interaction areas for the locations. These were marked by 18 yellow circles, as shown in Fig.2, but without any lines and text. The NKM group had no key map. The AKM group was given an ambiguous key with additional signs such as pen crosses and arrows. This allowed to verify variations in the interaction data also through the support of participants' comments.

The case holding the embedded Bela computer processing the sensor data and the audio, visible in Fig.3, was placed on the right, similarly to the laptop where the questionnaire was answered by all participants. The soundwalk was originally performed and recorded from TLP (the left bottom location in Fig. 2) to TLC, in a clockwise spiral. Participants were not aware of the original route followed.

2.3 Measures

In a pre-test questionnaire, we collected demographics, field of study, familiarity with areas presented in the map, and self-reported noise annoyance [22]. Participants were also asked to rate their experience in Sound, Acoustics, Architecture (No experience, Curiosity, Moderate practice and studies, Expert). In a post-test survey, another questionnaire collected the agreements to a set of sentences on the experience.

The use of the fabric was logged as sensor data to be aligned with the sonic content produced by the participants when experiencing the medium on their own. Interaction data consisted of time of activation of the 18 areas upon touch, triggering the correspondent recordings. The participant had to keep the finger on the area to continue listening, but releasing the finger did not reset the starting point of the recording. The time-stamped sampling of the sensors took place with 20 ms accuracy and allowed consistency between the sensor and the audio log. The data analysis started from the first touch and stopped after 290 seconds for all participants including one who decided to interrupt the experience after 3 minutes. For this person, the remaining time was filled with zeros.

The interaction data for every participant was summed for each location, with the name "Listening Time per Location" (LTL), measured in seconds. This measure was averaged across locations, and the deviation of the mean and the median was studied across the participants and the three groups, as shown in Table 2. Moreover, the first two locations chosen to begin the exploration were noted, and the exploration patterns across
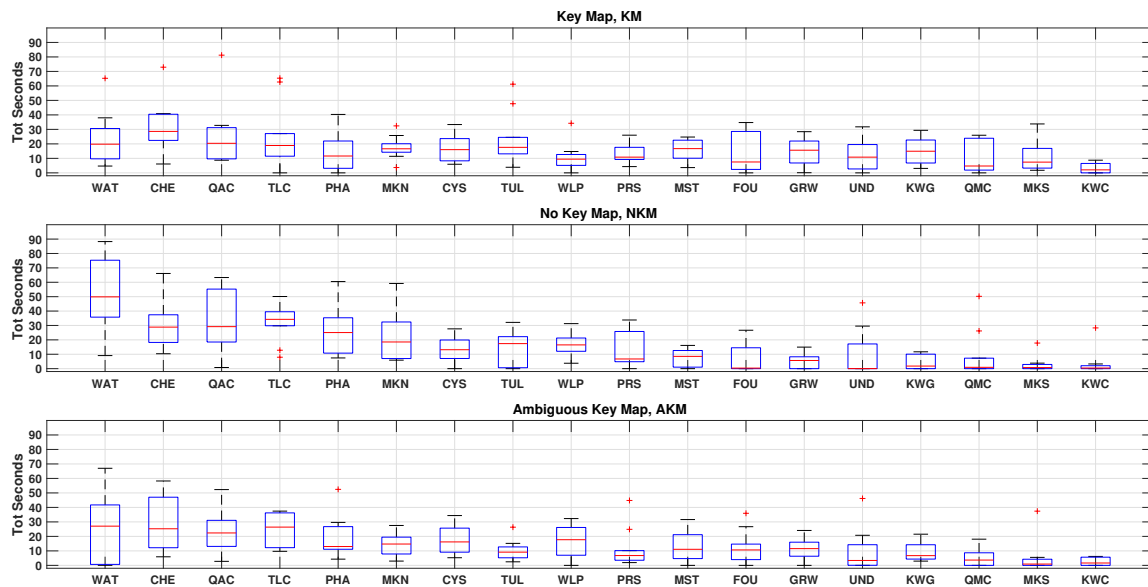
Fig. 4: BoxPlot distribution for the three groups under observation ordered by the entire group $n = 30$ mean, KM= Key Map, NKM = No Key Map, AKM = Ambiguous Key Map. On the y axis the total amount of time spent on each location in seconds, on the x axis the names of the locations

participants were visually inspected. The length of the interaction with every sensor was compared across groups and examined, for the entire length of the exploration.

3 Results

Fig.4 presents the boxplot distribution of the LTLs for the three groups. Table 2 shows the standard deviation σ relative to the locations' LTL. The standard deviation σ for the group with NKM is more than double than for the other two groups, KM and AKM. This result suggests that viewing the key may level the distribution of the time spent on each location. The key could enable the subjects to reach locations less obvious or respondent, but it may also create among the subjects the *duty* of exploring all the locations in the given time.

3.1 Aural Fabric without Key

For the group without the key (NKM), the most discarded locations were KWC and MKS. KWC was hard to press, as stated by some participants in the post-test interviews, whilst MKS was hidden between the more prominent TUL and MKN. Still, two subjects listened

| Group	σ mean T	σ med T
Key	7.0567	6.6147
No Key	16.8806	14.7386
Ambiguous Key	7.6095	8.5650
Total $n = 30$	8.8404	8.9173

Table 2: Standard deviation σ of the mean and median time (seconds) spent on every location by the three groups.

to them for longer, demonstrating the basic functionality of the interactive areas, without the aid of a key map. Similar more forceful interaction was required for QMC (echoey sound of a kicked stone and a ventilator), and KWG (opening door and some distant confounded sounds), which also received little attention.

Location UND, a quiet absorbent space with metallic sounds of clothes hangers and footsteps on carpet, was found with median and variance similar to FOU, where the walk ended, presenting a dynamic binaural appearance of the fountain water.

MST presented the steam-like sound of a double decker bus and received for NKM slightly less median LTL than for group KM and AKM. PRS, with low frequency
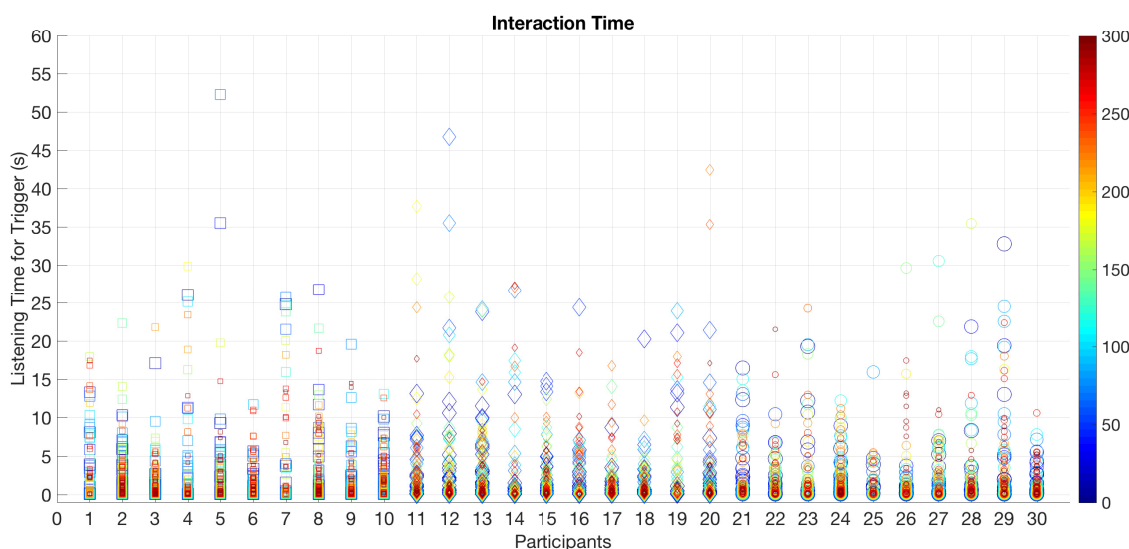
Fig. 5: Distribution of the listening time for each triggering (y axis) for each participant (x axis). Markers are bigger at the beginning of the exploration (in blue), and smaller at the end (in red). Squares for KM, Diamonds for NKM, Circles for AKM. The colormap on the right corresponds to the advancement in the timeline (s).
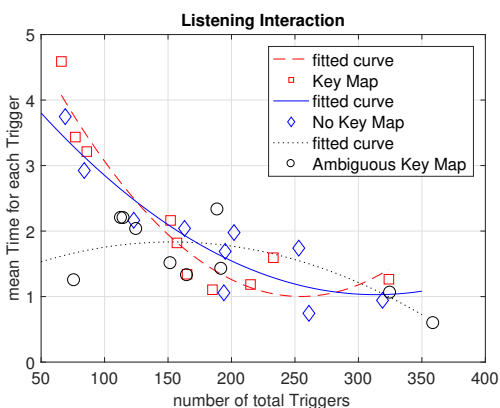

Fig. 6: Distribution of the mean listening time (y axis, seconds) for each triggering action versus the number of total triggers (x axis) for each participant. Red squares for KM, blue diamonds for NKM, black circles for AKM

loud industrial boat sounds, and TUL, with the narrow street resonance of a helicopter, presented similar median LTL for each of the 3 groups, with a slight median preference for TUL, and more variance for NKM.
Other locations presenting similar variance are CYS and WLP, geographically close, with similar open ambience, but with bird sounds and the appearance of unintelligible voices in the first case, and distant bird sounds, gentle splashing of water and fainted music in the other. Other pairs with similar LTL for the NKM case are PHA and MKN. Placed in geographically different points, they are both large halls, but PHA, the larger, presented mostly sounds of few distant reverberated footsteps and clicks, whilst the market presented a very busy scene with many present sources.

3.2 Prolonged listening

Four locations presented consistency of interest across participants: WAT had the greatest preference for the NKM case, with median LTL of 50 s, and listening experiences up to 90 s, 3 times the length of the recording. Reasons to be attributed to the visual appearance are that the area representing the river is the largest in the map and the only one with light blue colour, whilst reasons to be attributed to the sonic content refer to the general preference for water sounds, as reported in literature [23, 24]. CHE, visually equal to PHA but mirrored, streamed reverberated whistles and footsteps of a child stomping, mixed with highly reverberant ambiance. PHA and CHE presented about 15 seconds mean difference in LTL. This may suggest that apart from the visual appearance, the appreciation of the sonic content influenced the exploration of the map.
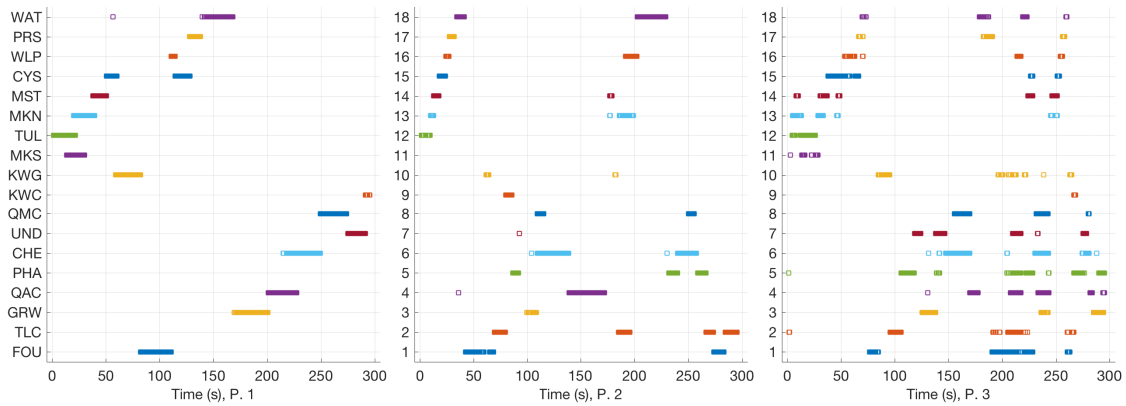
Fig. 7: Comparison of 3 different explorations starting from Turpin Lane (TUL). We observe in the 3 scores variable trajectories and complexity.
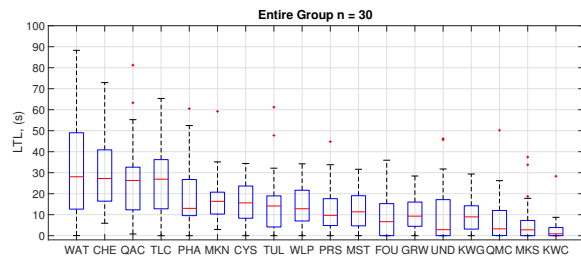
Fig. 8: Distribution of the values for the entire group *n = 30*, sorted by the mean.

Similarly, TLC and QAC are both courtyards with a similar open volume in plan and elevation. They are also symmetrically mirrored on the Aural Fabric, but they offered different sonic atmospheres which could have influenced their sonic exploration. A confusion of conservatoire music practice scenes was selected for TLC, whilst in QAC participants could listen to sounds of dragged footsteps on gravel and few reverberant vocalisations in the courtyard. For these two locations, LTL variance is mostly aligned in the KM and AKM case, with more extended whiskers in AKM for QAC. In the NKM case, instead, they both hold the median between 30 and 35 sec, but QAC has a much extended variance compared to TLC. This suggests that almost all the NKM participants listened to TLC in its entirety, possibly triggering it again, whilst QAC was found both interesting and not interesting.

3.3 Interaction trends

In Fig. 5 we present the participants' individual interaction events, showing that the interaction that

lasted longer (>30 s) happened at the beginning of the exploration (in blue) for participants 5, 12, and 29, and at the end for participant 20 (in red).

We measured how long the participants stayed on one location before moving to the next one. The individual interactions were averaged for each participant of the three groups, and these means are shown in Fig.6. On the left of the graph we find those exploring the map triggering the sensors less times with a higher mean time, whilst the right of the graph shows multiple short listening interactions. The participant on the bottom left interrupted the experience after three minutes, affecting the curve fitting for group AKM, otherwise similar to NKM and KM.

3.4 Effects of the key on the experience

From a qualitative perspective, 96,67% of the participants found the experience pleasant. ANOVA was run among the questionnaire scores to find significant differences ($p < 0.05$) related to the use of the key. Scale points were defined with 4 as neutral and 7 as strongly agree. AKM agreed less ($p = 0.015$, $F = 7.205$) in being interested in future soundwalks after experiencing the Aural Fabric (M = 4.30, $\sigma = 1.70$) than KM (M = 6.00, $\sigma = 1.05$). Similar values (6.10 and 4.50) but slightly weaker correlations ($p = 0.026$, $F = 5.848$) were found among these two groups with regard to being interested in making a collaborative map in the future. Instead, NKM group presented scores between the two groups (respectively M = 5.70 and 5.10).
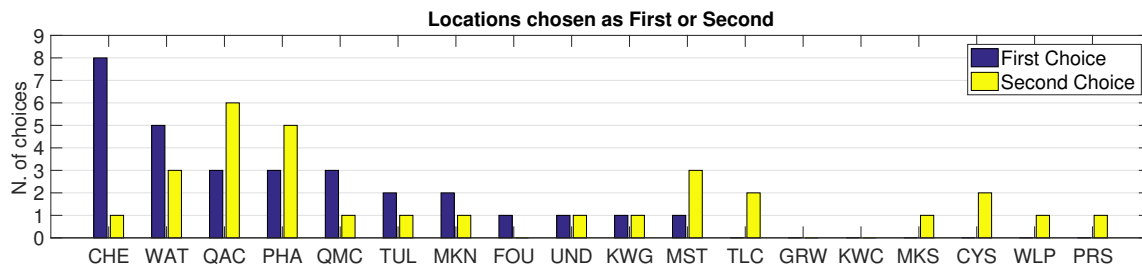
Fig. 9: Distribution of the choices related to the first location to explore (blue) and the second (yellow).

Moreover, the use of the correct key map increased the appreciation of the interaction compared to the group without key ($p = 0.045$, $F = 4.643$). KM group agreed more than NKM in defining the interaction pleasant ($M = 6.70$, $\sigma = 0.48$ against $M = 5.80$, $\sigma = 1.23$). Similarly, NKM found the Aural Fabric "not working as expected" significantly more than group KM ($p = 0.178$, $F = 6.813$, NKM: $M = 4.40$, $\sigma = 0.84$, KM: $M = 2.60$, $\sigma = 2.01$), although both means expressed disagreement or neutrality towards the sentence.

4 Discussion

4.1 Exploration strategies: walking and playing

In order to understand with more detail the exploration patterns, the interaction logs were manually inspected. In Fig. 7 it can be observed the route of three participants starting from TUL and MKN, who followed a path similar to the one devised for the soundwalk. The diagram illustrates different strategies in the way the route was traversed: exploring the locations only once (left), going quickly through all and repeating the exploration again, often overlapping two locations (middle), or playing more than one from the beginning, towards an instrument-like approach at the end (right).

Overall, about one third of the participants explored the map in a slow sequential way. Some participants reported in the interviews to explore the map simulating a walk, suggesting an exploration based on the cognitive process called *path integration* [25]. Another third of participants explored the map starting sequentially and mixing recordings towards the end of the exploration. This suggests that they stored the content of the recordings and the position in their memory, before playing them in a musical way, resembling a *landmark based navigation* approach [26].

However, Fig. 6 has shown how the key did not affect individual interaction modes. Thus, these might be more related to personal attitudes towards playing with interactive content.

4.2 Influences of starting point on LTL

Fig. 9 presents the histogram for the location preference related to the beginning of the exploration. The first location explored is shown in blue, the second in yellow. Amongst the entire group, CHE was chosen as first location by 8 participants, followed by 5 for WAT, and 3 for each QAC, PHA, and QMC. This data seems correlated to the ranking of the time spent by every participant on each location, as shown in Fig. 8 for the CHE and PHA, but is different for QMC.

QAC was choses as second location to explore by 6 subjects, PHA by 5, and MST by 3. Locations chosen for the second listening were more distributed in the rest of the map (3 never chosen), than for the first choice (7 never chosen). GRW and KWC were never chosen as first or second.

The mean of the group LTL for QMC was the third lowest (Fig.8), but it was chosen as the first location to explore by 3 participants, and second by 5. This result suggests that the initial vantage the location had in visibility was affected by other factors. These may be the lack of foreground sonic content, and surely the additional pressure needed to stream the sonic content, as reported in the interviews.

Within group NKM, CHE and WAT were chosen as first locations to explore by 3 and 3 participants, but WAT presented a median LTL of 20 second more than CHE. Within group AKM, CHE was chosen as first by 4, WAT by none, and CHE was listened to for 10 seconds more than WAT. For group KM, CHE was chosen as first by 1, WAT by 2, and the relative LTL appeared similar. These results are not sufficient to attribute any direct influence of the starting point on the location preference, according to the group conditions.

4.3 Improvements and future work

Results showed that the aid of a key significantly influenced how participants explored the Aural Fabric, reducing the preference for individual locations, measured here through the overall listening time per location (LTL). However, even the less prominent locations were found and listened to by some participants, without the aid of a key. In the future, detaching the content from the correspondent locations would allow to gather evidence on how the sonic content affected the LTL, independently from the visual appearance of the map. One complaint from the participants was the different level of pressure required for all locations, which should be uniform. This interface could be improved by stitching additional conductive threads on the top of these areas. Conductive threads should not be covered by other non-conductive colours. Having solved interaction issues, further investigations could address how people choose their route from the same starting point, including quantitative proximity analysis. We hope that other studies comparing a textile sonic map with a haptic screen-based version will show whether the physicality of the interface has an effect on the exploration of a given route.

The results from the questionnaires and the participants' comments provided overall positive feedback about the experience, for all groups. However, they remarked the importance of providing clear guides for users exploring soundscapes from a textile map. Although searching for hidden locations may be fascinating in playful contexts, interactive areas should all provide equal accessibility if aiming at soundscape awareness or research.

Finally, the study suggested new possibilities to research perception of sonic information and its spatial and mental organisation, in the field of virtual navigation of spaces. The artifact was originally designed as a medium to allow people to reflect on a given area and *hear* one glimpse of its character. However, the creation of alternative tactile sonic maps could present different perspectives on the locations originally chosen for this interface and provide new insights on their exploration and navigation.

5 Summary

We investigated how thirty participants explored, with or without the use of a key, a textile sonic map. The map conveyed a variety of sonic environments, binaurally recorded during a soundwalk. We found that the aid of a key affected participants' preference when listening to the different recordings, leveling their answers. The group without key presented a polarised preference towards locations standing out not only for the size and distinctive shape of the conductive area, but also for having pronounced foreground sounds as moving water, whistling, gravelly footsteps and music practice. Comparing the interaction data with the participants comments, it was found that the map streamed content immediately and intuitively from some interaction areas, whilst other areas should be redesigned to achieve effortless interaction. Nevertheless, the experience with the Aural Fabric was considered pleasant by the majority of the participants with strong agreement. It enabled discussions about the sonic environments of the recorded spaces and their acoustics, showing potential to engage the general audience and designers of spaces in sonic studies and practices.

6 Acknowledgements

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