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Wandertroper: Supporting Aesthetic Engagement with Everyday Surroundings through Soundscape Augmentation

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ABSTRACT

In this paper we present the design and evaluation of Wandertroper, a mobile system designed to support re-engagement with everyday surroundings during daily walks. Wandertroper generates real-time sound based on the spectromorphology of the inhabited soundscape, which is manipulated by how the user walks. Through an iterative participatory design process using semi-structured group discussions and 'in-the-wild' evaluations, we outline how design aspects, such as the degree of output abstraction and aesthetic personalisation of use, facilitated users' engagement with everyday surroundings. We discuss how Wandertroper turned daily walks into personally-meaningful aesthetic experiences.

Author Keywords

Embodied Interaction; Aesthetic UX; Rehabilitation of Attention; Soundscape Spectromorphology.

ACM Classification Keywords

H.5.1 [INFORMATION INTERFACES AND PRESENTATION (e.g., HCI)]: Multimedia Information Systems - *Audio input/output, Evaluation/methodology.*

INTRODUCTION

Smartphones have become ubiquitous, weaving their way into all aspects of our lives to support daily activities and modifying the way in which we experience, interpret and act in relation to our environment. Often information we access via these devices might be about the place where we are, yet the visual display draws our attention, isolating us from that environment [26,34]. Digital stimulation from notifications, media and 'apps' is always available, causing an overabundance of information dividing our attention, and isolating us from the environment [10,26,53]. Although Simon's observation that *'a wealth of information creates a poverty of attention'* [48] was written in the 1970's, it remains relevant today when considering the ways in which we use smartphones and other mobile technologies.

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Figure 1. The final version of Wandertroper being worn on the arm. The armband allows the device to be positioned and oriented in different ways. These influence the mobile sensors, which affect how the sound is manipulated. The external microphone was optional, and was often not used in practice.

Even without smartphones we often lack attention when walking in very familiar environments, relying on cognitive filters to prioritise information that is essential to navigation, and discarding that which is perceived as unnecessary [49]. This selective attention allows efficient movement, but make us less aware of familiar environments [34,48]. Everyday surroundings are taken for granted, so we miss opportunities to connect and engage with the unique, hidden or other personally meaningful aspects of everyday places [34,39,48]. This contributes to a cycle in which we begin to consider everyday places as uninteresting so we retreat further into a 'digital bubble' [34,53], walking through familiar places in 'autopilot mode' whilst interacting with mobile devices. In this paper we consider how this same mobile technology can be used to support re-engagement with everyday environments, allowing users to see those environments with fresh eyes.

Curiosity is a property of attention that can be wielded to seek what is intriguing about everydayness. Research has shown how curiosity and connectedness with our surroundings is important to well-being [18,27,42], such as i.e. by facilitating meaningful experiences and general feeling of satisfaction [27]. There has been significant work on stimulating curiosity towards familiar urban environments by the artistic community, such as street events (e.g. www.fluxus.org) and psychogeographical practices [28]. Recently HCI has begun to consider how everyday walking activities can be augmented with interactive technologies. Primarily this has been through the auditory augmentation of the environment to support 'eyes-free' interaction [7,21,35]. Sound can also be generated dynamically from real-time sensor data generated as the user walks. Such reactive interaction removes the need to explicitly interact with the device [14,16,19]. The mapping of this sensor data onto sound characteristics can be designed to clearly refer to aspects of the surroundings and direct users' attention towards them.

However, existing work using environmentally sensed data to manipulate sound mostly used non-aural environmental characteristics (e.g. camera input [5], or temperature and humidity [16,19]) rather than manipulating sounds already present in the existing soundscape. Existing work has also considered the augmentations as the primary purpose why individuals would be walking rather than supporting re-engagement with the environment during everyday walking activities in familiar places (e.g. walking to the shops).

To investigate these issues, we present the design and evaluation of Wandertroper (Figure 1) a mobile application designed to hedonically re-engage users with their everyday surroundings. Wandertroper dynamically manipulates existing environmental soundscapes during everyday walking activities, based on their specific spectral characteristics and users' physical movement (captured via inertial sensors). Our goal is to enhance rather than isolate, contextual elements that users would otherwise filter out, and stimulate curiosity towards familiar places.

RELATED WORKS

In order to effectively augment daily walks, we need to understand how individuals engage and make sense in them. To do so we consider multidisciplinary accounts from embodied interaction [6,13,24,25,32], psychogeography (*'the study of the precise laws and specific effects of the geographical environment, consciously organized or not, on the emotions and behaviour of individuals'* [29]) [8,28,51] and soundscape composition [1,46,50,52]. These clarify how individuals make sense in everyday-life by employing all their senses (not only sight), interpretation and imagination. As well as how common walks are experienced not only to achieve functional goals, but also hedonically for the pursuit of pleasure, enjoyment, and wellbeing [11,27,33,39].

Embodied Interaction

Embodied interaction theories highlight how attention is strongly influenced by our engagement with a situation [13,23]. Situations have a relational nature: our relationship with the lived space depends on interdependent personal, spatiotemporal, social and technological aspects [9,13,55]. Therefore, an understanding of engagement has to take into consideration how we organise our interaction and make sense of it in relation to these multiple dynamic elements. We do not make sense only out of visual cues, but multimodally [6,11,40], through our entire body and movements [22]. We experience everyday environments in an embodied way, by being present in them. Previous studies proposed embodiment as a way to re-engage users with environments by leveraging on how the entire context of interaction (not only the information in the interface), contributes to the creation of meaning [12,24,25]. 'In-the-wild' evaluations and participants' direct account of their interactions [31], have proven to be useful tools to understand how holistic aspects real-life experiences (e.g. attention, behaviours, feelings, imagination, enjoyment and meaningfulness) relate to specific design aspects of technologies, and re-design accordingly. However, existing work that focuses on engagement with the surroundings through audio [5,30,35,54] often fail to consider embodiment and its importance during evaluation.

Aesthetic Walking and Dérive

Hedonic aspects such as emotions, memories and aesthetic sensitivities all contribute to the creation of a pleasurable experience [11,55]. Imagination plays an important role in our understanding, engagement and feelings during daily walking [19]. To deal with this complex relation between human attitudes and the urban environment, research methods are often inspired by practices from cultural and artistic communities. Interaction design research has increasingly considered psychogeographical strategies, such as the *dérive* (a drifting walks through the physical space of the city, with a focus on the psychophysical effects of the exploration of the landscape) [8,51], as a way to trigger and analyse experimental behaviours, imaginative reworking and creative exploration of the urban environment [19,31,36,44]. However, using psychogeography as a design method would constrain the walking activity [3] (e.g. individuals attempt to walk through the environment in a particular way – such as in a *dérive*-like drifting) and would not help us understand how everyday walking is affected by the use of the designed technology.

Psychogeography could instead be used as evaluation tool, to observe if "*dérive*-like" explorative attitudes emerge from the use of different applications in real everyday walking contexts (such as walking home from work).

Soundscape Composition

Sonification is an effective way to present information and allow 'eyes-free' interaction, without requiring visual attention on a device [20,26,35]. Acoustic ecology [46] and soundscape composition theories [52] have considered how different levels of attentiveness and understanding of the world are influenced by the level of abstraction (perceivable distance) between the manipulated sound and its real world source. The degree of abstraction affords different interpretations of what the sound refers to. For example, low distance (abstraction) between a sound and its referent will draw direct attention to a particular feature (e.g. the sound of a dog barking will be clearly heard as such), whilst greater abstraction due to soundscape manipulation will allow wider interpretation of what the sound refers to (i.e. the dog barking will sound ambiguous and open to other interpretations). However, these theories have been largely studied and employed in pre-composed soundscapes (e.g. in gallery exhibitions or concerts), rather than in situated real-time manipulation of the current soundscape we study here.

Which relations with the inhabited space would different levels of sound abstraction, augmenting the existing soundscape, trigger in the listener? In order to engage users with their surroundings in more personal and aesthetic ways, the sound feedback abstraction has to be designed to also trigger more imaginative thoughts that still relate to particularities of the contextual situation. Attention has to be directed on how users will move with it *'from surface-level of an environment, recognising its sound sources and ambiences, to the mental world of psychological and cultural associations, memories and symbolism provoked by those sounds, and then to the unbounded world of the imagination'* [52].

Existing HCI Research

Existing commercial and research systems have considered supporting the relationship between an individual and his or her environment. However, the majority of work has sought to explicitly inform the user about specific elements of the surroundings. For example, common locative media services such as Foursquare (www.foursquare.com), Google Maps or playful tourist guides [4]. By their nature, such applications are more useful in unfamiliar environments to support reaching a specific destination, rather than wandering in familiar environments.

Other locative media projects have sought to enhance environmental exploration and re-discovery using different kinds of digital annotations of media related to physical, social and historical characteristics of the inhabited space [2,21,35,41,45]. Media art works have supported hedonic and serendipitous ways to explore the city through augmenting specific routes. For example, Serendipitor (serendipitor.net), Likeways (likeways.wordpress.com), or maps of others' walking trajectories and emotions [37,43]. Such approaches show that new, often hedonic insights [11] and perspectives about familiar places can be supported.

However, mobile systems that rely on visual media content (such as maps) can easily redirect users foreground attention towards the mobile and away from the environment [38,49,53]. For this reason sound feedback has been found more suitable to engage users with their surroundings while walking [7,21,35]. Furthermore, media content mostly generated and selected by other users[5] or algorithmically [35], can fail to correlate with personal and current experience of the environment. For example, *a* geo-located audio 'tweet' may refer to past events or weather conditions that vary significantly to those experienced by users when hearing it *in-situ* [35].

Other work has maintained a more embodied link with the inhabited space by using real-time audio augmentation. Some used sound processing to remove urban noises by transforming them in into more pleasant sounds [54]. Other work increases awareness of invisible and non-aural physical phenomena (such as light, temperature humidity etc.) in collaborative [16] or individual experiences [19,30]. Unlike these projects, which aim to direct users' attention towards the sensor data, our goals is to use that as a means to re-engage users with the environment.

More similarly to our intent, Sonic City [19] aims to direct users' attention towards the surroundings in a psychogeographical fashion, but through a wearable sensing garment using non-aural data to generate a musical soundtrack as a user walks through the city. However, it was not evaluated to understand how users' overall attitudes and aesthetic engagement with the environment was influenced.

'Sadly by your side' (SBYS) [5] is a more contemporary example using mobile camera sensed data to manipulate the audio of pre-composed musical tracks (via timbre, melody and volume change). In this case environmental data are of secondary importance, and serve only to partially affect the pre-composed songs. Again, as an artistic experience, it has not been evaluated to determine the impact of personal attitudes towards the environment.

Droumeva and Andrisani [14] carried out an embodied 'in-the-wild' evaluation of an RjDj (http://rjdj.me/) app which distorted and de-familiarised the soundscape on group soundwalks [1]. Although it was not a design goal of the app, they found it was able to facilitate interaction between the participants but the generated sound was fatiguing. Additionally, the RjDj app was studied as part of a soundwalk, where the goal was to explicitly attend and consider sounds when walking. How the sound processing was designed was not reported, and because of the attention towards the soundscape, we do not know how users' consideration of the environment was influenced.

To the best of our knowledge no work has yet considered how the relationship between the environment and the real-time augmentation of its soundscape through embodied interaction, could be designed to promote users' curiosity and aesthetic engagement with familiar environments. How could opportunistic yet aesthetic perceptions of those environments, be triggered by unordinary interaction with ordinary smartphones?

STUDY OUTLINE

To investigate how a more embodied approach to mobile interaction design might help re-engage users with familiar environments, we carried out a 5-phase iterative, participatory design process (Figure 2).

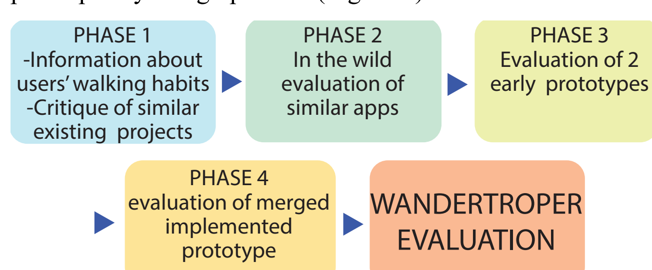

Figure 2. Structure of the iterative participative design process

This started from considering existing sound-augmentation approaches, continued by outlining the design and evaluation of design iterations, to the final design and implementation of Wandertroper.

Six participants took part in all phases of the study, aged 23-34 years old, 4 males and 2 females, from different nationalities (US, Germany, Ireland, Cyprus, China). Participants previously knew each other and the researchers. That participants already knew each other was intentional as a way to support the effective critiquing shown to be important in prior work on UX design [31].

We employed a range of techniques through the different stages, including collective documentation analysis about existing projects and mediated walks in everyday environments self-reported in the group meetings. Participants met five times as a group (once at each phase of the process outlined in Figure 2) to discuss their personal walking experiences, both un-mediated and mediated by existing applications and study prototypes. Discussions were audio-recorded, transcribed and coded through a grounded theory approach to determine emergent themes [17].

The following sections outline the first four meetings and their key findings. The fifth meeting, covering the final group evaluation of Wandertroper, is then discussed.

Phase 1: Unveiling Walking Habits and Attitudes

In the initial phase participants discussed their daily habitual walking activities, and what they did on these (e.g. what they were thinking about or paid attention to). We also introduced video and audio examples of two existing soundscape modification systems discussed in the background section: Sonic City [19], and Sadly by Your Side [5]. This served to introduce the project and how soundscape augmentation might enhance everyday walks.

Key Findings

As already discussed by studies dealing with selective attention [34,48] and attentional blindness [49], participants noticed that they used vision primarily to make sense of new places, while in everyday surroundings it was almost 'shut off', being used for other purposes and often re-directed towards the mobile device. Consequently, participants also dislocated thoughts from the current situation to focus on mundane activities (e.g. what to watch on TV when arriving at home etc.). Instances of attention towards the surroundings were sporadic and depended on particular, environment related, activities. P3 for example described that during a street cleaning strike she had to pay more attention in order to not step on rubbish along the way. P1, who was researching the street sport Parkour (https://en.wikipedia.org/wiki/Parkour), commented on how this had drawn his attention more towards the environment: *"doing my thesis for architecture I was studying parkour and it is a different way to think about the city or whatever and until you don't start practicing [...] you'll not see different things."* (P1)

In considering the documentation about the existing soundscape modification systems, participants found Sonic City to be very complex, with an over-analytical mapping of data to sound that may make it difficult to get a holistic view of the data. The relation between sound and represented elements in the surroundings should be clearer, while also providing more scope for subjective freedom of imagination and interpretation. The wearable was also considered very bulky and unpractical for daily use: *"I would never dress up all that every time I exit"* (P3)

In comparison, *`Sadly by your side'* [5] provided easier usage but invited gazing to the camera detection process visualised in the monitor to make sense of the unclear relations between music and environment: *"what is changing? what is the red and blue making? I need to watch to understand, but I still do not get it, do you know?" (P2). "no" (P1,3,5).* Participants speculated that if the sound was always dominated by the musical track used, rather than by specific aspects of the environment, *'every place [would] sound the same, like the album'* (P2).

We identified that a balance between both approaches was a better choice. This regarded using common technology that was easy to use during everyday walks (such as smartphones), whilst providing interaction modalities that did not encourage gazing at the device (such as by using a visual display). Avoiding overtly pre-composed sounds, and balancing between sound complexity and clear coupling with environment were all important issues.

Phase 2: Testing Existing Applications

In the second phase we chose two existing applications that were similar to those discussed in Phase 1, but were able to be run on users' devices. Participants with iOS (P3, P5, P6) used RjDj (scene "Dimensions"), discussed in the related work. Participants with Android devices (P1, P2, P4) used Scene-Player (https://puredata.info/downloads/sceneplayer) a clone of RjDj with two different manipulation techniques ('scenes'): Atsuke and World Quantizer. These applications generate audio derived from mobile sensor inputs of the device, and augment the real world auditory environment using different sound design strategies. These range from dance-beats repetitions (Atsuke), to more synth-based distortions (Dimensions) and delay (World Quantizer). Participants used these applications individually over a week, as and when they wanted, during everyday walks.

Key Findings

During the second group discussion a primary critique was directed towards the effects and distortions used. The sounds produced using Dimensions scene resembled more gaming experiences, rather than reflecting the actual atmosphere of the surroundings. Atsuke's dance beats and voice distortions quickly became out of place and exhausting, whilst World Quantizer usually encouraged users to stop, and start to compose music (such as by beating on objects and singing). In all cases attention was re-directed towards the device and interaction with it, and away from the environment.

From these we considered that a more psychogeographical-like relation between sound and environment is important. User's behaviours, moods and the existing soundscape should all be incorporated. Without carefully basing the modified soundscape on existing activities (e.g. soundscape nuances and users walking actions), it is easy to further isolate users from the environment.

Phase 3: Initial Prototypes

Based on the findings from the first two phases, we developed two initial prototypes. These served as a proof of concept on sound synthesis strategies: Additive Synthesis and Dynamic Delay. We chose these as a way to compare how a more abstract (Additive Synthesis) and literal (Dynamic Delay) relationship between sound and the environment affected user engagement with it.

1) Additive Synthesis

A basic additive synthesis engine determined the most dominant frequencies in the environment and played them back. In the basic additive synthesis only three pitches were played back (the fundamental and two partials). This was achieved by a Fourier analysis performed in Pure Data (PD, www.puredata.info/). This was meant to provide a direct representation of physical environmental characteristics, whilst preserving an abstract relationship between the sound and its real world referent (by playing only the main raw frequencies).

2) Dynamic Delay

The environmental soundscape was replayed with a delay. Users set the delay time via a slider. This allowed variation in the levels of abstraction between sounds and environment. This provided a more direct relationship between the sound and its real world referent.

Both applications were developed using PD with MobMuPlat (www.mobmuplat.com) providing a basic UI to manipulate the audio parameters, and could be run on both Android and iOS. In both prototypes, the raw microphone input is directly outputted at low volume to avoid isolation from the surrounding soundscape caused by the headphones. Participants were given both applications to use over one week during their everyday walks.

Key Findings

After a week of use participants met in a group to discuss their use of both apps.

1) Additive Synthesis

Despite its abstractness (straight forward un-modulated pitches), the Additive Synthesis supported a strong connection between the physical environment and the modified soundscape. The additive synthesis reflected environmental sound densities, punctuated by the occurrence of higher-volume incoming sounds that stood out from the existing soundscape. For example, participants noticed how in a calm situation such as an afternoon walk in the neighbourhood, tones were influenced by sporadic noises, such as a dog barking or birds singing. In noisier contextual situations, changes in pitch happened when cars passed closer in the street or when people spoke.

However, some situation such as walking through busier environments (e.g. the Saturday market in town), caused rapid dynamic changes in the sound, rendering the feedback disturbing, and the relation with the environment unclear: *"I was sitting in the bus and it sounded pretty much always the same, but then I exited in the market and everything started to change very fast with the voices [disturbed tone]. Then there were some girls playing the violin at a corner and the tones synchronised…that was fun, I never paid attention to the sounds and rhythms of all the things around me"* (P4)

In such busy environments, with higher frequency of event sounds, changes of pitch occurred very quickly making it difficult to couple the changes with the corresponding environmental source. The sound response became instead clearer in response to more periodic sound detected (such as a violin playing) as the feedback changed more slowly, making its relationship to the real world referent much clearer. To support clarity, the sound engine required implementations aiming to ease the processing of dynamic and aperiodic sounds encountered in the different real world experiences (e.g. unexpected background noises, unpredictable changes in frequency and amplitude).

2) Dynamic Delay

Users noticed that by simply affecting the delay time they could allow for different levels of sound abstraction ranging from simple distortions at shorter delay times (40-100ms) up to echoes and longer loops with sequencing characteristics at longer delays (500-10000ms). This engendered interesting dynamic levels of sound defamiliarisation that enhanced users' curiosity towards the environment. The delay also afforded reflective attitudes towards the elements of the existing soundscape by distorting them and opening interpretation regarding the location of their source: *"For me it was interesting today, there were parts just where the little horse is, and when we left the place I believe the horse made a noise also and I really couldn't tell where that noise was coming from, it could be everywhere, so for this reason I was sometimes looking around"* (P1). However, users did find the need to use a slider to modify the delay distracting because it requires them to stop walking and look at the device in order to customize it.

Both prototypes were found to be useful in connecting sounds to the environment, and encouraging users to think more about their everyday surroundings. A solution merging both prototypes could engender a more intriguing feedback based on different layers of sound abstraction. However, in order to avoid distractions due to interaction with the display, participants suggested that the delay time should be linked to body movements, better reflecting the ongoing walking action and reducing display distraction.

Phase 4. A Combined Prototype

Following the suggestions from the feedback in Phase 3, we combined the features of both Additive Synthesis and Dynamic Delay into a single prototype. The accelerometer of the device was used to control the delay time. Participants could therefore directly affect the delay time based on both how they moved, and the device orientation (as the accelerometer would be affected by this).

Let's assume the example scenario of a participant walking with the mobile in the trousers pocket. At every step (when the leg is lifted) the mobile main axial orientation (Y) gets misaligned relatively to the vertical plane. The gravity force acting on Y will so cause an increment in the raw signal of the accelerometer proportional to the degree of misalignment. In this way a more horizontal mobile position (e.g. person sitting) would cause longer delay times and a more vertical position (person standing) would generate shorter delay times. Walking oscillations would cause extensions and contractions of the delay time as well. This constitutes a direct mapping of information related to walking movements (mobile oscillations and orientation) to the audio feedback (delay time).

We made further refinements to the auditory manipulation to sustain the synthesis of diverse and not always predictable soundscapes (e.g. with periodic and aperiodic sounds, different noise levels and background sounds). Bandpass filters were used to deal with disturbing tonal extremes or constant background noises (such as wind or traffic). An amplitude threshold was updated every second based on the soundscape decibel mean. Only sounds greater than this were considered for manipulation. For example, a passage from a silent alley to a busy market square would be augmented, but then be removed. This helped avoid both sonic overlaod (as seen in Phase 3) as well as constant silence. To better support customisation, a slider was provided for calibration of the delay's decay.

Key Findings

As in previous phases, participants used the prototype on their own device over the course of a week, before taking part in another group discussion on their experiences.

The merged solution was found aesthetically pleasant, especially because it allowed users direct influence and some control over the sonification through full body movements, referencing users' behaviours. In considering how the prototype had been used it became necessary to reflect on where the device was worn, as the accelerometer responds differently depending on its placement. Various placement options were discussed. Participants noted that holding the device in the hand or in the pocket, or in different degrees of orientation, generated different effects. With the mobile in a lower pocket of the trousers the delay was increasing every time the user took a step, and decreasing once the leg returned perpendicular to the ground. The consequent perceptual effect was described as a *"time contraction"* (P2) or as *"a glass ball bouncing fast before stopping"*(P5). Participants suggested that having a holder for the device would have allowed for experimentation of how different movements and orientations influenced the sonification.

Participants found the ability to control the delay decay allowed tailoring to different environmental soundscapes and moods by decreasing (or increasing) the importance of the delay: *"Last day […] I was tired and there where a lot of persons with different bags from the market making different noises, and I thought that was very nice to hear the frequencies that these generated. So I decided to put the slider [delay decay] down to hear better these frequencies while relaxing"* (P5).

This highlights that as environments are all different, a standard augmentation may not be suitable for all. Decreasing the delay decay caused the sounds coming from the additive synthesis layer to be better heard, increasing its musicality: *"(…)I imagined it would be nice if they could form a music like, all these frequencies that enters, like something more complex that let the frequencies clear but make them sound maybe at different moments, a little mixed..."* (P5).

WANDERTROPER

Feedback from Phase 4 was incorporated into our final version of the app: Wandertroper. As with the previous prototypes, this was developed in PD using the MobMuPlat Editor to provide a GUI. As suggested from Phase 4, we provided an armband (based on a sports band for holding the phone during exercise) to allow positioning the device on different parts of the body such as arms and legs. This allowed different body movements to affect the sonification (e.g. more horizontal position will cause longer delay times), and hands free use. A directional external microphone (Belkin F8Z818eb) was made available. As there was only one this was passed around members of the group over the three week evaluation period.

Sound Synthesis

We modified the sound synthesis techniques to take into account the suggestions that emerged in the fourth group discussion.

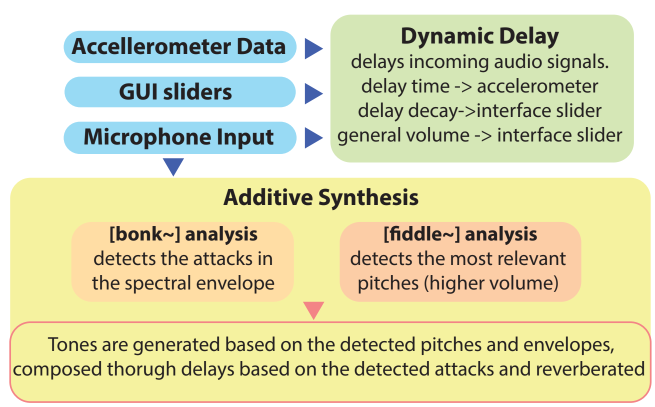

Figure 3. Outline of main sound processing blocks and relation between interface, sensors and audio synthesis.

We added a delay volume slider, allowing users to personalise the impact of the Delay filter in different environments and consequently adjust the dominance of the Additive Synthesis. A spectrum analysis based on PD [bonk~] object was implemented to detect the 'attack' of sounds in the environment. These amplitudes are used in the additive synthesis to modulate the amplitude of the played-back partials. The generated tones are then reverberated and played back based on the attacks originated from the [bonk~] analysis. In short these implementations allow for a more musical additive synthesis based on different attack times and amplitude modulations (Figure 3)

EVALUATION OF WANDERTROPER

Wandertroper was installed on participants' own devices, and was used for a period of three weeks, as and when the participant wished during everyday walking. This allowed us to get a more long-term view on how Wandertroper was used. Participants most often used Wandertroper alone, integrating it into existing activities, such as when walking to school, the supermarket or leisure walks in the neighbourhood and city centre. A group walk along the river flowing near the university campus was also conducted with all the participants as a group shadowed by the researcher. A final group discussion was held at the end of the three-week period. Recordings of the discussions were transcribed and coded using thematic analysis [17] Five main themes emerged: 1) attention to surroundings, 2) attention to behaviours, 3) sound abstraction, 4) aesthetic daily walks, 5) general use and customisability.

Attention to Surroundings

The delay effect played the predominant role of creating ambiguities in the locations of sounds. While this was noticed with the previous prototype, the mobile holder accentuated this experience. Participants were able to better position and orientate the mobile on arms and legs, customising the delay effect (for example, a slight turn of the device could increase the delay time – due to causing a higher reading on the accelerometer). This eased the understanding of the sound feedback in relation to the walking practice (arm/leg oscillations and orientation).

More specifically, the emergent sound ambiguities caused attention to be focused towards the environment to identify likely sources, reengaging users with it: *'…there was a dog barking and I believed it was coming from the path in front of me but I couldn't really see it from the bushes. So I took out an earphone, 'cause I wasn't so sure, and I discovered the barking was picked up when I was rounded in the opposite direction, and then delayed in the direction of the path. So actually there was a dog far away, but it was in the field at my back'* (P4). This could also lead to duplication of the sounds, making them appear as if from two places: *'a bird was up my head and I could hear the position of it directly, and then I was hearing the loop of it that was sounding just like if it was in a different position than where the bird was, and then I tripped over as it flew over my head from a different place, and it sound like the localisation was kind of jumping between the two'* (P3).

From the temporal shift of these sounds participants constructed a layer of new connections and possibilities related to the augmented place. These emergent practices engaged users in a re-understanding of the de-familiarised environment that enhanced their curiosity towards it.

Attention to Behaviours

The sound manipulation strategies initially encouraged users to adopt playful walking practices to manipulate and control the soundscape manipulation. For example, sometimes users tried to synchronise their movements with the rhythmic sounds of delayed steps or cars passing by: *'The delay related to position made me try to play with things like cars passing by, simultaneously changing the mobiles position - I tried to create a reflection on the impression the cars made on me. But this can also happen unconsciously because not only the app creates a sound that is connected to my steps, but also I will try to walk in a speed that matches the sound, it lets me be in the flow'* (P1).

While these playful behaviours were later abandoned for more common walking, awareness of walking movements remained highlighted by the sound feedback itself. Both delay time and the density of tonal composition based on the additive synthesis related in part to users' movements. This highlighted awareness of both arm and leg movement while walking, as well as transitions between environments with different characteristics: *'It seemed like that when you would stop and stand still it would go silent. Then there's times in which you would hear one two tones creeping and the little swallows, but as you're moving they're kind of constant, in the background. That difference is really nice because it really heightens your sense of standing still, you kind of sense or figure more stand than usually or you're just more aware of it'* (P3). These relations between movements and soundscape increased the sense of embodiment in the world, making users more consciously aware of themselves and their actions.

Sound Abstraction

Whilst the ability of users to dynamically control and influence the sonification manipulation engaged them with their surroundings, unlike with RjDj [14] it did not support composition of music and thus detract from the environment. The influence of the real soundscape, and its role in driving the audio, would always disrupt any compositional attempts. Attention was therefore maintained towards the wandering experience rather that towards the musical result: *'if you try to mix and keep on something, it gets modified by what you are listening in that moment…the desired result can't never be fixed, it slips away with you, together with the changes in the natural soundscape […] it has to be constantly redefined out of what you have heard, what is happening and what you will do, it is contingent to your being there in that very moment […] I feel more like to slip into the flow of different physical rhythms, ways, and mental suggestions'* (P2).

The multisensory experience of a walking activity, in which sight plays a principal role in daily actions, allowed users to experience the de-familiarised soundscape without feeling overwhelmed or disoriented. *"Sometimes I put out one plug and I thought that the effect was not so different...but [at the same time] the effect is actually quite strong…I didn't really think about the fact that it was repeated in that moment…was just another way of perceiving it."* (P4).

Aesthetic Daily Walks

An aesthetic experience is defined as *"an experience qualitatively different from everyday experience and similar to other exceptional states of mind"* [33]. Turning everyday walks into aesthetic experiences does not mean turning usual places, urban sounds and noises into beautiful objects (in fact ugly things can elicit aesthetic experience too [15]). It rather implies an enhanced attention, imaginative reworking and feeling of unity with everyday experiences as objects of beauty [33,55].

Wandertroper allowed aesthetic appreciation of everyday surroundings to emerge by stimulating attention, mental reworking and personal connection. The more mindful attitudes engendered by the interaction allowed participants to pay more attention not only to sounds, but to all the senses such as smells and peripheral vision. This often triggered memories and imaginative thoughts, reinforcing the experience of the everyday surrounding, and augmented by a more personal layer of meanings: *'there were some moments in which I was paying a lot more attention to the smells around me and together with the music they recalled sensations and images. Probably eased by the fact that I was stopping more and in a sort of attentive-relaxed attitude. […This…] recalled me like a memory of me [when I was a] child […] and this emotional atmosphere was added to the actual landscape and mixed, to fade away. It was really suggestive [...] and new images where suggested while walking, shaping the flux of my imagination'* (P5).

Wandertroper affected users' attitudes towards familiar places. The re-working of soundscape elements in relation to walking movements supported users awareness towards common aspects of daily walks in a way similar to the psychogeographical dérive. Voices and bags at the market, fast cars on the main road and leaves on the river path were exemplar objects of attention. The aesthetic emphasis on such components of the everyday walks, rendered the experience of the different location more unique and defined, each place more "placeful" [47].*'I feel like more awake while walking in a known place, more explorative, like when I just arrive in a town that I don't know and I'm fascinated […] the pub will have a predominance of particular tones and sound densities related to people flow, and the river more fixed tones and sort of different characterising elements, nuances, harmonies and my sensations added'* (P4)

Beyond being used to rediscover and engage with existing, familiar, everyday places, participants also expressed their curiosity in exploring unknown places too: *"I'd like to go in more noisy environments like construction areas along the street, a kindergarten, for this reason ...everywhere could be like an audio park, you just need to know the right places for what you're searching for"* (P3)

General Use and Customisability

The mobile holder allowed positioning the device in multiple locations on the body and at multiple orientations, allowing the users to affect how their physical movements were incorporated into the sounds. Most participants preferred to wear the device on the arm (3 on upper arm and 2 on forearm), only one wore it on the leg (Figure 4). The length of the headphone cable made it awkward to wear Wandertroper on the leg. This also limited the positions and orientations of the device, allowing less variation in feedback. No participants used Wandertroper connected to the belt or backpack as this lead to little change in sensor values due to movement: *'I really like to wear it on the arm, today was nice because there is always this oscillating movement while you walk, and so in the delay time. And I thought the sound outcome reflected better my position also when I stand still. In fact, if I think about it now, it was because when I stop I tend to cross the arms or putting the hand on my hip, in this way the mobile is in a more horizontal position causing longer delay times that really fitted my situation of standing and contemplating, just relaxing'* (P2).

Figure 4. Wandertroper being worn on leg. The mobile holder allowed users to position the mobile in different parts of the body. However, users largely preferred wearing it on the arm.

Participants often used Wandertroper *ad-hoc* during walks, rather than taking walks with a particular intent to use it. Coupled with a specific need to obtain the external microphone, it was often not used. Participants justified their preference arguing on the easy availability of the inbuilt microphone while using Wandertroper mainly in unplanned interactions, while the external microphone required pre-planning. However we may speculate that also the microphone size and explicit shape may have contributed implicitly to this attitude by appearing indiscrete to use in public. The microphone was considered an interesting design solution as it allowed the user to point at specific area of interests surrounding him/her: *'I can point here and there […] is very interesting because you focus more selectively and further, so you can pick up more particular sounds [...] The soundscape is augmented with different, more selective elements. So for example the fountain is not just there, but the dropping keeps walking with you, and mixes with you stepping on a leaf or you opening a door of a building... your paces on a wooden floor, and then another room and a different soundscape, the oven, the kitchen sounds, the espresso machines and little spoons ticking in the cups'* (P6).

Participants found that simple hardware modifications allowed (such as the optional use of the external microphone) played an important role in framing their experience by further customising the system. Allowing users simple hardware customisation is a factor to consider in designing for user personalisation and appropriation.

DISCUSSION

Wandertroper was designed to support engagement with everyday surroundings through sound mediation, enhancing situational curiosity and mental reworking of daily walks. Several design considerations have emerged from this process. We discuss how each of these helped us to envision a system aesthetically engaging users' with everyday surroundings and suggest future similar research.

Iterative Design and In-the-wild Evaluations

The iterative design process, informed by multiple field evaluations and users' direct accounts, allowed us to study how design choices affected understanding, mental-reworking and behaviours in real walks. Multidisciplinary accounts from embodied interaction, soundscape composition and psychogeography, helped in framing our research approach and evaluation methods. We methodically considered these contributions in the iterative design process in order to improve the system everyday use in terms of feedback clarity (soundscape composition) aesthetic focus (psychogeography), and interaction fatigue (embodied interaction).

Users could actively participate in the iterative development by suggesting improvements based on their personal real-life experiences with different prototypes. Evaluating prototypes 'in-the-wild' made it possible to identify otherwise unpredictable characteristics of real-life interactions (e.g. situated human attitudes, environmental phenomena, technological mediation) and the interplay between cognitive, sensual and emotional aspects of experience [55]. The group discussions allowed us to collectively analyse how specific design choices affected walking activities of participants with different sensitivities (aesthetic, technical, practical, engaging). Finally, familiarity between participants eased collaboration: analysis and critique of each others' experiences.

The high quality feedback arising from the interplay of the 'in-the-wild' and participatory evaluations allowed us to conduct design interventions in a relative short time: hardware extensions and sound-synthesis solutions (e.g. filters, conditional gates, timed updates) alongside the existing objects for music composition. We therefore encourage design approaches which couple multidisciplinary theoretical contributions with iterative participatory processes and 'in the wild' evaluations to improve the design of pleasurable, everyday interactions.

Degree of Output Abstraction

As suggested by soundscape composition, attention has to be paid to the user's ability to understand and relate the sound feedback with elements of the surroundings based on its distance (abstraction) from real world referents.

Through the evaluations in real-world scenarios and participants direct accounts, we identified how a balance between the complexity of the sonification and its level of abstraction from the real world referent supported associations with environmental aspects [52]. In comparison, related studies used overly complex mappings [19], focused more on musical composition rather than on inhabited places [5], or enhanced playful engagement mainly by distorting sounds in easily fatiguing ways [14].

Specifically, we found simple sound repetitions (delay) could be interpreted in different ways while walking in real places. Longer time delays sparked curiosity about possible other locations of the sound source (e.g. voices of children heard in a different neighbours' garden, or traffic sounds appearing to come from the river). Shorter delays enhanced proprioception awareness by responding to walking oscillations, reflecting different body positions states of activity (e.g. sitting or standing). Emotions and sensations about places were also altered just by differently reverbing and echoing sounds in space (at even shorted delay times).

The additive synthesis triggered both analytic interpretations based on the direct representations of environmental physical characteristics (spectromorphology [50]), while also constituting a more musical background line. In these ways Wandertroper's audio feedback emphasises particularities of the existing soundscapes and walking behaviours, while allowing re-interpretations and mental reworking of the relationship between audio and the nearby surroundings.

Designs aiming to engender particular attitudes in sound-mediated interactions, should therefore consider how feedback is interpreted based on its level of abstraction in relation to contextual aspects during usage.

Personalisation of Use

Wandertroper does not have a specific function of use and was employed in different walking scenarios. In order to support this freedom, basic sound calibration is necessary. However, users also need to customise parameters on-the-go, without needing specific skills or interacting with the display in a way that distracts from the environment.

In Wandertroper the basic GUI and the armband for on-body positioning supported simple and quick personalization. Users could easily and quickly set parameters accordingly to their mood, or particular aspects of the soundscape. This allowed users to promptly engage with Wandertroper 'on-the-go' and in their own ways, without being distracted by setting up multiple parameters and settings in the app: playful walking, more aesthetic wanders, employing audio feedback as a way to analyse different environmental characteristics and motivate exploration of known and unknown places. Similarly to psychogeographical practices such as the *Dérive,* users could focus on more aesthetic and subjectively meaningful aspects of everyday walks through familiar environments.

The challenge for designs aiming to engender personally pleasurable human-environment mediation, is to design calibration and customisation that minimally distract from the interactive experience. Wandertroper achieved this by facilitating on-body device use, automatic sound calibration through mobile orientation and user control over the audio gain (of the delay effect and its decay). Other designs may require different strategies aiming to support the desired modality of interaction.

LIMITATIONS AND FUTURE WORK
Our work has shown that the ability to manipulate the level of abstraction between a sensed sound source and its representation in Wandertroper can have significant impact on the interpretation of everyday environments. However, we have only considered a small number of possible sound manipulations. Future work will consider how further levels of abstraction, by manipulation of additional parameters, can provide different insights into familiar environments. Given participant's comments on experiencing novel places using Wandertroper we also hope to compare how the experience of use changes between familiar and unfamiliar environments. Longer-term studies will allow us to consider how uses and attitudes towards the environment evolve over multiple months of interaction with Wandertroper.

CONCLUSION
To conclude, we found that Wandertroper re-directed attention towards walking behaviours and surroundings in personally meaningful and aesthetic ways. Different explorative attitudes (both mental and physical) are supported towards familiar places. Wandertroper supports reflective walks characterised by more aesthetic considerations of the surroundings and the user's relation to them. In this respect our findings emphasise the employment of iterative participatory design processes that can be facilitated by familiarity between participants, in-the-wild evaluations, attention towards the degree of output abstraction and aesthetic personalisation of use. Wandertroper is an example of how a familiar technology can be considered in a different way, to affect how we perceive and act in the world by enhancing our curiosity and aesthetic engagement with it.

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