Walk this Way: Musically Guided Walking Experiences

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ABSTRACT
Musical soundtracks will be important features of future locative experiences from tours to games. We present a study designed to uncover potential relationships between higher-level musical structures such as harmony, melody, timbre, dynamic intensity and punctuation and users' spatial experiences. We observed twenty-two participants exploring an open field while listening to four contrasting musical compositions, and then interviewed them afterwards. We report their different approaches to interpreting the music, strategies for mapping zones, choice of stopping destinations, and their awareness and appreciation of the music. Our discussion of these findings in relation to the literature leads us to propose six initial principles to guide the composition of mobile and locative soundtracks, and also to articulate a three-layer framework of global, regional and local attachment to help guide the attachment of musical features to different regions within a locative experience.

Author Keywords
Location based experiences; conceptual metaphors; music composition; attachment; design

ACM Classification Keywords
H5.m. Information Interfaces and Presentation (e.g., HCI)

INTRODUCTION
Musical soundtracks provide the essential backdrop to many of our most compelling experiences. They dramatically shape our emotions when watching films and drive our behaviors when playing interactive computer games. The spread of mobile music technologies over recent decades, from the Sony Walkman to current smartphones, means that music is increasingly embedded within peoples' everyday activities [2] and that mobility and locality are common drivers of musical experience [5]. People now routinely select music to accompany physical activities such as jogging or cycling and share music through their favourite locations [19].

Given that people are already curating their own mobile soundtracks, an interesting related question is how might skilled composers deliberately write musical soundtracks for mobile experiences? What principles might guide them to establish powerful mappings between music and spatial experience that enhance both? This is a complex question, potentially involving multiple and multifaceted relationships between music and spatial experience. At one extreme, we know that music can invoke strong emotional responses. At the other, previous research has shown that the nature and spatial placement of sound can help drive fine-grained navigation [6] and that humans physical actions synchronize in response to musical tempi [20], an effect utilized in sports and exercise routines [5, 13] and of course, in dancing.

We focus on one particular form of relationship between music and spatial experience – one that has not been previously reported in the HCI literature. Our study concerns the relationship between *musical structure* and *guided walking*. By musical structure we refer to the key structural elements of music such as dynamics, melody, harmony and timbre. By guided walking we mean mobile walks and tours where people explore an extended space that might benefit from a musical soundtrack.

Thus, we are interested in a level of musical structure that sits between the thematic (traditionally associated with manipulating emotions) and the sonic (previously coupled with spatial cues). Our question is whether such intermediate levels of musical structure might guide key aspects of spatial walking, for example, cueing users when they are approaching or entering new locales or regions. Such a relationship, should it exist, would enable composers to create new compositions, but also to adapt existing ones, modulating and mapping them onto particular spatial settings and arrangements.

We therefore present a formative study in which we invited participants to follow various musical compositions, each structured around different underlying musical elements (timbre, harmony, dynamics, melody), as they explored an open space. Rather than creating simple musical statements based solely on the individual structural elements and test them in isolation, we chose to compose fully formed musical extracts. We felt it was important to consider the balance between these structural elements and other musical content (i.e. the melody's accompaniment). This also provided the participants with an authentic listening experience that assisted us in capturing a range of supporting data, such as their thoughts and feelings. Our findings inform proposed

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mappings between the manipulation of melody, harmony, timbre and texture and guided walking. They also suggest that there may be a scalable notion of attachment, where music can drive spatial attachment at global, regional and local levels. These findings establish an agenda for further research that may lead to a framework for the structural composition of musically mediated walking experiences.

RELATED WORK

Relevant related work spans three areas: explorations of composing mobile and locative music; experiments to explore how (non-speech) sound can guide navigation; and discussions of spatial metaphors in music.

Explorations of composing mobile and locative music

The capability of modern mobile devices has inspired app developers, composers and artists alike to create new mobile music experiences. Within the field of *locative media*, location and movement have operated as both a producer of content and a stage for content delivery [21]. *Soundwalks* convey location-themed narratives, combining recorded ambient sound, music and narration [9]. Augmented reality experiences such as *Sensory Threads* [7] aim to re-focus the user's perception of their environment, via generative soundtracks controlled by location, environmental and bio-data. RjDj produce *"sonic experience"* apps, working with source material from film soundtracks such as *Inception* and *The Dark Knight Rises* to trigger music sympathetic to listeners' intensity of motion [18].

Contemporary composers have embraced interaction and context to shape new musical forms. Jorge Drexler's '*app songs*' (n1, n2 & n3) utilize the exploration of location to unlock a song's instrumentation [11]. BlueBrain have pioneered '*location-based* albums' composed for The National Mall Park in Washington and Central Park in New York respectively [1]. In this case, GPS data triggers musical fragments attached to specific locales, which combine to form a continuous musical experience that is shaped by a listener's chosen trajectory and pace [1].

Collectively, these examples reveal a growth of interest in the creative potential of mobile and locative music, which motivates our attempt to uncover deeper compositional principles or guidelines for this new medium.

Experiments in (non-speech) sound navigation

Non-speech audio has been widely explored as an alternative to speech based spatial navigation systems. Their musical approaches can be divided into two categories: those which use auditory spatialization techniques to mirror spatial movement [6]; and those which develop a vocabulary of musical sounds to communicate instructions [16], or to represent places, or objects [10]. Studies to date provide evidence for usable connections between some facets of music and direct spatial navigation tasks. However, these are working with a limited musical palette at a relatively low level of detail (e.g., spatializing sound). Our interest lies in finding other useful relationships between higher-level musical structures and spatial experience that might support the application of traditional compositional techniques to the creation of mobile musical soundtracks.

Spatial metaphors in music

Psychology, linguistics and music theory have much to say about relationships between musical structure and spatial experience**.** The [3] theory of embodied meaning explores the idea of *image schemas* as structures within our cognitive processes that enable us to construct conceptual metaphors for embodied experiences. As physical beings, so the argument goes, humans better understand non-physical concepts, for example music, when they are referenced through spatial metaphors such as containment, orientation, space and force. *Image schemas* provide a rich currency for the description of music [3, 4]. Some commonly applied musical image schemas are: c*ontainer* – e.g., this music is *in* the key of 'A'; *verticality*, *force* and *balance* – e.g., this melody rises *up* and *resolves* on the tonic of the *scale;* and *melody is movement along a path (source-path-goal)* – e.g., this melody *starts* on a *low* 'F', before *reaching* a climax at *high* 'C', then concludes on a high 'F'.

This discussion of cross-domain mappings concerns the *physical* (source) *to musical* (target). A further body of research has sought to explore the inverse *musical* to *physical* mapping. Studies have shown that these metaphors can be both visualized and manifested physically, for example musical 'intensity contours' (i.e. crescendo, accelerando) can be interpreted as changes to physical speed, distance and approach, whilst pitch can suggest vertical and horizontal movement [4, 14]. Other work has explored the application of conceptual metaphor theory into the design of music software user interfaces, physical interaction design and music analysis [22].

Music is often viewed as a temporal contour, progressing towards points of *arrival* [17]. The overarching form of a composition is then formed around a succession of episodes punctuated by these points of *arrival* [17]. In turn, the field of music cognition reveals that listeners learn to anticipate common melodic, rhythmic and dynamic events [15] such as the resolution of harmonic cadences and the climax of dynamic crescendos. In short, motion and arrival is central to musical form, being both perceived and anticipated.

To summarize, the growing interest in composing mobile and locative music motivates a desire for a more principled way of relating musical structure to spatial experience. At the same time, prior research suggests that the answer may be found in various conceptual metaphors that map between musical and spatial structure. The following study is designed to explore the potential of such conceptual metaphors in composing musical soundtracks for walking experiences.

STUDY DESIGN

We have carried out an open-ended quasi-experimental study to uncover potentially interesting and actionable relationships between aspects of musical structure, and walking behavior. Inspired by the conceptual metaphor theory, we composed four pieces of music that responded to spatial location. Participants then walked around an open field while listening to these compositions. We observed their behaviors and interviewed them afterwards in order to understand their experience of the music and how it had influenced their walk around the field.

The musical compositions

The four compositions (C1-C4), each drew inspiration from one or more of the image schemas and related cross-domain mappings reviewed above. They were based on four principal elements of musical composition – dynamics, harmony, melody and timbre. Each of these elements were embedded within a fully formed musical extract, to maintain a traditional compositional approach and a normal listening experience. Dynamics refer to the volume of an instrument or collection of instruments; presented as either single events or as graduated contours. Harmony, relates to a temporal sequence of chords (a set of notes played simultaneously). The melody is a sequence of single notes, which creates the tune. Timbre is the term used to describe the tone colour of an instrument, or texture formed from multiple instruments. Each composition contained five sections to create a musical journey from a start, to a point of arrival as shown in Figure 1 (zones 1 to 5).

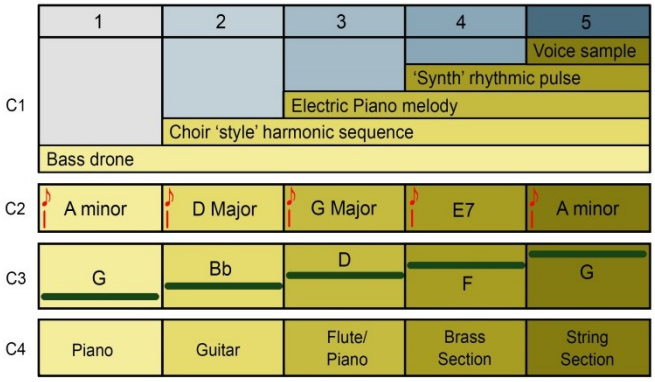


Figure 1: Visualization of composition arrangements

Beyond our deliberate variations in the compositions, the music was intended to be generally neutral, adopting an ambient electronica style that did not suggest any particular mood or theme. We encourage the reader to listen to the compositions, which accompany the paper, before reading further.

Composition 1 – Increasing voice density

Inspired by the conceptual metaphor of *crescendo (growth) infers motion towards* and *diminuendo (reduction) motion away* [4], this composition created a dynamic intensity contour by varying musical texture (Fig. 1: C1). A new musical voice was introduced in each successive zone to create an increasingly complex texture of musical activity. On reaching Zone 5, all five voices could be heard simultaneously.

Composition 2 - Harmonic motion & Dynamic punctuation

Composition 2 (Fig 1: C2) combined two components: *harmonic motion* and *dynamic punctuation.* The former applied a common sequence of five chord changes in the key of *A minor* (*container* image schema [3]), which started and resolved on the tonic chord (*balance* image schema [3]). As z1 & z5 both contained the tonic chord, a simple melody was added to z5 to differentiate it from z1. The *dynamic punctuation* component consisted of a single accent at the beginning of each section (Fig. 1: C2) to highlight the transition between sections.

Composition 3 - Ascending melody

This composition was motivated by two conceptual metaphors: *ascending pitch moves up, or towards* and *descending pitch moves down, or away* (*Verticality* image schema and *melody is motion along a path* (*Source-path-goal* image schema [3])). A simple rising melody was presented over a repetitive backing track (Fig. 1: C3), which resolved upon reaching Zone 5.

Composition 4 - Timbre

Instrumental timbre is an important compositional tool. Changes of timbre present a change of state and are often used to introduce new ideas or treat new sections. Our choice of timbre was also inspired by the *container* image schema, for example the statement that *'this music was played by a Piano'* suggests that the music emanates from within a *container* that is the piano. This composition explored whether participants would experience a sense of progression when transitioning through a series of different timbres. The music remains consistent across the five sections, only the timbre changes (Fig.1: C4).

The spatial experience

We chose an open field consisting of a grassed area surrounded by boundaries (three sides of hedge rows, one side car park) as the study location. We chose an open field as a neutral location with no objects or obvious meaning in order to remove any distractions. We designed four different spatial layouts, each of which consisted of five nested zones that were centered on different points around the field (see Fig. 2 for an example). Each of our musical compositions could then be directly mapped onto any of these spatial layouts, with section one of the compositions' corresponding to the outermost zone (z1) and section five the innermost (z5) (Fig. 1). The music faded to silence when participants moved outside of the outer zone – and faded back up upon re-entry.

As a result, we created 16 distinct walks – four compositions x four spatial layouts. These were implemented in *Calvium's App Furnace* as 'apps' for an iPhone 4s, with each app using the mobile phone's GPS

data to trigger the appropriate musical sections as users walked through the different zones.

Figure 2: Zone mapped onto study location

Task

Participants were given a general exploratory task, being asked to walk around field and *'listen to and follow the music, and if at any point they felt they had 'arrived' at a location where they wanted to stop, they were to conclude their walk'*. Participants were not briefed on the functionality of the system or placement of the zones. They were informed that the music playback may fade to silence at times and it was left open to their interpretation what to do when this happened. The task duration was flexible. However, an approximate ceiling of 15mins per task was presented, at which point the investigator would end the task. Each participant completed four walks listening to each of the compositions mapped to a different spatial location. The order in which they experienced the compositions and the allocation of these to the spatial mappings was randomized across participants, so that the different compositions and spatial mappings were completed in different orders. The participants started each walk from the same location.

Participants

Twenty-two participants completed the study, recruited principally from students and staff from the host university. The participant group consisted of an even number of males and females who spanned an age range of 18 – 35 years. They were rewarded with a small gift voucher. Thirteen had no prior musical experience, eight had self-taught an instrument to a low level, while one had some formal music training.

Data capture and analysis

We gathered three types of data. First, we observed people's behavior in the field, recording notes onto a handheld recorder. Second, participants'' movements were captured by GPS logs, which were supplemented with application logs that showed when different musical sections had been triggered. Third, post-task interviews were recorded onto a Dictaphone to uncover the participant's subjective view on what they did and why.

Our analysis triangulated these sources of data to build a rich picture of how participants responded to our compositions as they navigated the field. We coded our observations and GPS/application logs to produce a record of the zones that they crossed, the order of these crossings, their stopping destinations and their behaviors at these various key moments. We then compared this with participants' own reflections on their behaviors and awareness of the music.

FINDINGS

We present our findings under two broad two themes: how the music appeared to influence participants' spatial exploration; and how aware were they of the different aspects of the music?

Spatial exploration

General strategies

We observed a range of interpretations of the task instructions and a number of behavioral strategies during the study. The large majority of participants attempted to interpret the music. This group can be divided into those that assumed an orchestrated destination existed and attempted to 'crack the code', and those who explored the space, experienced the music and then chose a destination based on a musical preference. Two participants adopted a strategy of matching the mood of the music to a specific locale within the study area, exploring until a 'best fit' was found. One outlier used the music to inspire an imaginary environment - their destination choice was not chosen in response to any musical section or event, but in response to having formed their own virtual world.

Constructing a spatial map of the music

We asked the participants how they used the music to explore the space. In response some described a process of 'mapping'; forming associations between the music sections and areas in the study environment, which in turn informed their route and destination choices. Eight participants referenced this process in composition C1, six in C2, none in C3, and four in C4: *"I map the location with the music and I try to find where it makes me feel good (C1)"* and *"Piano is level 0, Guitar is level 1 and Flute is level 2. So, sometimes when I walked into a different area where I think level may be going down to the previous levels. So, I stop and change a bit" (C4).* One participant discussed playing with the *harmonic motion* component in C2, *"It felt as if I was kind of composing a rough score to something as I was walking along. I noticed you could interleave the two samples of the slightly higher and slightly lower versions if you kind of zig-zag along here which was kind of enjoyable" (C2).*

Impact of zone boundaries

As participants crossed zone boundaries, which triggered the sections of the compositions, we observed over half of the participants engaged in one of the following three behaviors: a sudden slowing of walking pace, or stopping momentarily, before continuing on, *"The first time when I noticed the music change, I just stopped for a few seconds"*. Others would stop and walk slowly backwards and forwards, appearing to engage in boundary testing, by

attempting to re-trigger the section, *"It sounded like another layer of music over here, and I tested it out by walking backwards and forward a couple of times" (C1)*. While a few would walk in tight circles, which encompassed one or more zone boundaries, appearing to deliberately re-trigger music sections.

Destination choice

The post-task interviews reveal a set of re-occurring themes that categorize the motivations for the choice of stopping destination, as summarised in Table 1. While we make no claim to statistical significance here, inspecting the rows of this table reveals a range of reasons for stopping. The first three rows (green) show that in the large majority of cases, participants stopped in response to a structural feature of the music that they found intelligible. A notable and somewhat unexpected case, which we discuss in more detail below, was stopping in response to one or more repeated moments of silence. The second three rows (orange) show the relative minority of cases where participants found the music less intelligible and stopped because they had had enough, or where they stopped in response to external or other factors.

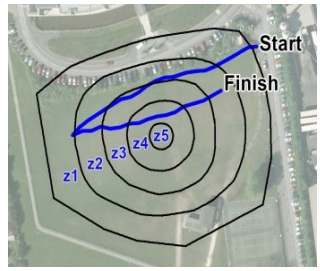
Rationale	C1	C2	C3	C4
Stopped in response to music	54.5%	45.4%	27.3%	36.4%
Stopped in response to silence	22.7%	9.1%	4.5%	4.5%
Stopped after repeated instances of silence	9.1%	4.5%	9.1%	9.1%
Wanted to stop	9.1%	18.2%	31.8%	18.2%
Environment factors	0.0%	13.6%	18.2%	22.7%
Other	4.5%	9.1%	9.1%	9.1%

Table 1: Destination choice motivations

Inspecting the columns of this table hints at some possible differences between the compositions as we discuss below. While there is no great difference between them, C1 appears to have been the most intelligible while C3 appears to have been the least intelligible, with more participants choosing to give up when they had had enough, an impression backed up by their comments.

Composition 1:

Six participants chose either z4 or z5, reporting they were attracted to areas of higher musical intensity, *"I found it here where the music plays strongest, where all the instruments play"*. Conversely, three participants chose locations which contained a lower musical intensity (Zones 1, 2 & 3). Three highlighted the 'vocal' sample used in z5 as a contrasting sound, which they interpreted as revealing of the destination, *"This one had a bit of distorted vocal in it at one point, and I think the human voice just grabs your attention"*. Of particular note in C1 are the seven participants who stated their arrival point was in response to encountering silence. Only two of these seven actually concluded their walks outside of z1. Four stopped within z1 and one in z2 whilst playback was still functioning. These participants felt that the reduction of texture diminished the musical momentum, signalling the end of their experience and the point of arrival.



"The music has been quite slow all along, and then when I was coming back it started to get up-beat, and then when I was walking in this area it went slow again, so it was natural, just felt like stopping (p9)*"* (Fig 3).

Figure 3: Participant 9 – C1

Composition 2:

Ten out of the eighteen participants, who concluded their walk within a zoned area, chose either z1 or z5, where the *'A minor'* tonic chord sounded (eight in z1 and two in z5): *"I was just drawn to this point. The only point that makes me think it's here is that it's* [sounds] *a bit stronger"*. The two participants who stopped in z5 were drawn to the addition of the melodic theme not heard in the other zones, *"When I got round here there was a more percussive piano piece came in that I hadn't heard before"*. Four just stopped not feeling able to choose a destination.

Composition 3:

Of the seven participants who acknowledged the melody component in C3, only one chose *z*5 as their destination as "*the pitch was at its highest"*. Two participants stopped in z2 because a sound faded out there, *"I think because there was a kind of underlying keyboard sound, I think, and when you get here that keyboard sound fades out"*. Seven participants were unable to locate an arrival point from the musical stimuli, *"It just felt that I was not being led anywhere, so I thought I would just stop and tell you"*. While four used environmental stimuli to drive their destination choice, *"The waves of repetitiveness in the music seemed to be reflected in this row of trees"*.

Composition 4:

Eight participants chose destinations based on a preference to a particular instrumental timbre, *"It just sounded nicer as I was walking along this middle bit"*, and *"I think I prefer the flute more, so I came back here"*. In contrast, five participants presented a destination rationale related to environmental stimuli, *"Because this music makes me want to walk around somewhere where they are flowers"*. Four stopped, not being able to choose a destination, "*I think I was trying to let it lead me somewhere, but it just wasn't happening! I felt like I heard all the parts there were to the piece"*.

The impact of silence

The impact of silence functioned as both a driver of spatial behaviour and a destination choice. The 22

participants completed a combination of 88 tasks (4 compositions x 22 participants). There were 35 examples of participants spending the full duration of their walk within the zoned area (having once entered the outer-zone). On 53 occasions participants left the outer-zone once or multiple times (maximum 7), upon which three different behavioural responses were noted.

Typical behaviour (38 instances) saw a heading modification to re-discover music playback, which eventually concluded with choosing a destination location within the zoned area (some encountered further instances of silence, but repeated the re-adjustment behavior).

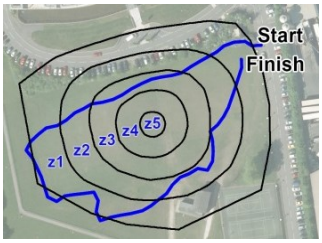


Figure 4: Participant 3 – C1

"I went to one point and I felt, like 'oh, this is the place', and I went the music stopped and then it was like "no", this is not the place I want to be because the music stopped there" (p3) (Fig. 4).

However, a few participants (7 instances) concluded their walk upon first exposure to silence (Fig 5), being prompted to halt their walk in response to the silence.

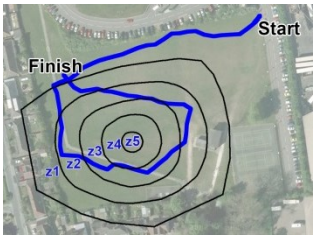


Figure 5: Participant 19 – C2

"I think the music stopping aborts the experience, so I didn't feel the urge to necessarily start it again" (p19), and *"The music stopped, so I felt like I had reached somewhere"*.

While some (8) adjusted their heading to re-discover music playback, then continued on to encounter further instances of silence, upon which they halted their walks outside of z1 (min 2 - max 6 instances of silence), *"So, I keep walking, it's quite frustrating and when I'm walking it stops again, so I think I don't want to listen to that anymore, and stop here"*. We observed these behavioral responses across the four compositions. The GPS logs reveal two participants chose a silent destination on C1, four on C2, two on C3 and three on C4.

Impact of Dynamic punctuation in Composition 2

The *dynamic punctuation* component in C2 appeared to be a distinctive feature for eight participants. Six of these eight participants suggested it signalled either the discovery of something, or a point of arrival: *"Every so often a drum would go down and make me want to stop and look around"*, and *"I got a feeling like I'm finding treasure";* whilst two participants suggested the accents were markers that were leading them somewhere, *"Every time I heard that harsh tone I felt that I should change direction, maybe it was leading me somewhere"*.

The repetitive nature of Composition 3

In contrast to the other compositions, C3 was described by many as very repetitive. C3 was the only one to contain a strong 'dance music' beat, which impacted on the act of walking for a few, *"I just think if the music is long enough, I'll keep walking"* and *"kind of exercise music, it felt like you were supposed to just keep going"*.

Awareness of the music

In this section we present participants views on their awareness of the composition's sections, their perception of being led, music enjoyment and their on-task attention.

Awareness of the compositional features

The participants were not asked directly about the compositional features just general questions about how the music shaped their walking experience.

In C1, 11 of the 22 participants reported an awareness of the compositional component, with some accurate terminology: *"I found one spot where there were at least five or six different layers"*, and *"Music sounds were coming in and more instruments"*. Others used more descriptive language: *"It starts off with a low sound and then it kind of gets louder and louder"*, and *"the music grew stronger at first, then grew weaker and weaker"*.

C2 revealed 12 direct descriptions of the *Dynamic Punctuation* component, *"Came to another spot marked by a percussive ring sound"*, and *"Every so often a drum would go down"*. While eight presented a nebulous recognition of the *Harmonic Motion* component, *"I think the tone changed at some point, it seemed to get lower at one point, or go down a scale or something"*.

C3 witnessed only five participants directly reference the *ascending melody* component, *"I stopped where the pitch was at its highest"*, and *"definitely a violin piece in there"*. Three suggested hearing possible changes to the overall volume of the music, *"I'm not sure whether that was actually a change in the volume or just my perception"*. This perception of volume change may be as a result of the rising pitch, which can be viewed as musical intensifications [4].

In C4, 13 participants were explicit in their awareness of the compositional component, *"Yeah, the instruments. First it was just the piano and then the guitar started playing and then violin"*.

In summary, participants reported a broadly similar awareness of key compositional components, with the exception of C3 where the ascending/descending melodic component was not as readily heard and discussed.

How much they felt led by the music?

Participants answered the two questions at the end of each task: *'How much did you feel led by the music?'*(BL) and *'How enjoyable was the music?'*(ME). Both used the same rating scale: 1 = *not at all* – 9 = *very much*. Table 2 presents the mean scores.

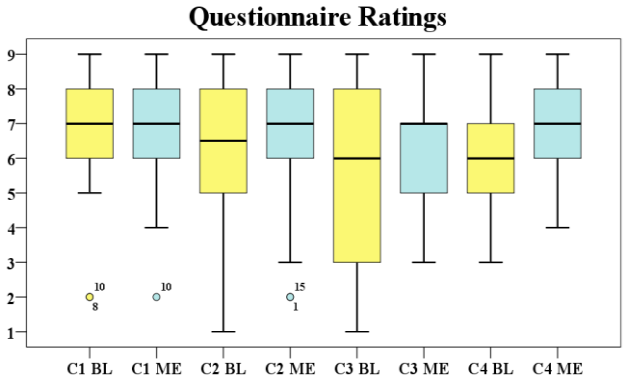


Table 2: Mean questionnaire scores.

Bivariate correlations of the questionnaire scores do not reveal anything statistically significant. C3 scored lowest for 'being led', which is consistent with the previous comments about the generally unintelligible *ascending melody* component.

How enjoyable was the music?

By and large, participants enjoyed the four compositions, describing them variously as, *"chilled", "relaxed"* and *"enjoyable"*. The questionnaire rating reveals a similar picture. A few prominent responses were noted however. The *bass drone*, which formed the music section for z1 in C1, was described as *scary, tense* or *dangerous* by seven participants upon first exposure to it. However, when participants' had walked through the other zones the feelings of suspense and fear were replaced by largely positive emotional responses. Six of the participant felt at unease with C2, *"Makes me feel tense, I want to find somewhere that is safe"*, whilst in C3 some were a *"little bit bored because it was repetitive"*. C4 provoked strong feelings of sadness, contemplation and nostalgia from eight participants, *"It's more like listening to a sad story", "Very calm, actually"* and *"It reminds me of something. It's about the memory of someone!"*

On-task attention

We asked the participants what they were focusing on during the tasks. On the whole they disclosed an even distribution between the music and the environment (C1, C2 & C3). Two participants' disclosed being preoccupied with their thoughts on C1. A group of participants were uncertain where their attention was placed during C3, whilst three stated their initial focus on the music gradually drifted in response to its repetitive character. In contrast to C1-3, eight participants in C4 placed their focused on the environment, and eight were engrossed in feelings of sadness, contemplation and nostalgia.

Walking Speed, Distance and Duration

Analysis of walking speed commenced from participants z1 trigger point (initiation of music playback) until termination of their walks. A repeated measures ANOVA was performed and pairwise comparisons between the four compositions show a significant difference between C3 and the other three compositions (C1-C3 $p = 0.002$: C2-C3 $p = 0.000$: C3-C4 $p = 0.001$). 6 participants discussed a perceived increase of walking pace on C3, *"made me walk in some kind of velocity,* and *"I carried on walking, just getting into that pace"*. No significant differences were observed on task distance or duration.

DISCUSSION

We now consider how our findings, in the context of the wider literature, shed light on key relationships between musical structure and spatial experience. We focus primarily on three particular elements of musical structure: intensity contours (through crescendo and diminuendo), arrival (through harmonic resolution and dynamic punctuation), and containment (through timbre and silence).

Intensity contours

We observed on the whole, that participants could follow the dynamic intensity contour presented in C1 and that it shaped walking behavior. However, there was variation in the choice of final destination, with some following the rising contour to a destination in the centre zone, whereas others were equally attracted by the diminishing contour that led them back out to the start. So, the first half of our metaphor, *crescendo infers motion towards,* appears to have some purchase, but it is less clear whether *diminuendo infers motion away*, holds as strongly. This contrasts with previous research that suggests that a rising contour prompts spatial approach, while a diminishing contour is manifested as motion away [4]. In considering explanations for this difference, we need to discuss the purpose of intensity contours in music.

Crescendo

Intensity contours, such as crescendi, transmit the music to another musical point by building or retracting tension. Crescendi are then reconciled by that tension's release, which may be considered a point of arrival [17]. The form of this release could be a change of key, a new melodic theme or rhythmic feel. Within C1, no release stage was present, so no point of arrival; the contour just peaked at z5. Thus, participants' would not easily have known when they had reached the peak of the contour, which may have resulted in a tendency for them to walk out the other side and continue onto move down the diminishing contour.

Diminuendo

At this point it is worth discussing the subject of listener expectation. Listeners passively learn, through repeated exposure to common musical processes such as harmonic resolutions, changes following even numbers of cycles or the ubiquitous 'fade out' during the final chorus in pop song recordings [15]. With this in mind, the group of participants who chose the lower zone (z1), where the intensity contour had reduced back to a simple bass drone, may have expected that the diminishing intensity contour had led them to a natural conclusion, as often happens at the end of a piece of music. We therefore note that a

diminishing contour can imply a path towards the conclusion of a music-mediated walking experience. In contrast, a rising intensity contour requires a point of arrival to be reconciled.

Arrival

We explore the idea of musical arrival in relation to two key musical ideas: harmonic resolution and dynamics.

Harmonic arrival

The *harmonic motion* component in C2 was not commonly acknowledged and we speculate whether the *Dynamic Punctuation* accents, which were prominent in the audio mix may have partly masked, or distracted the participants from fully recognizing the changing chord harmonies. We observed almost half the participants choose a destination in a zone containing the tonic chord (z1 & z5) and they mostly struggled to explain why, "*The only point that makes me think it's here is that it's* [sounds] *a bit stronger".* This quote could be interpreted as a tacit recognition of the common resolution that a return to the tonic chord provides. Brower argues that the inherent attraction of the tonic chord in tonal music requires that it is returned to at the end of a composition, to resolve the harmonic journey [3]. These placements of this chord create a harmonic *balance* (image schema) [3]. Whilst exploratory at this stage, it appears that strong harmonic resolutions possess some capacity for communicating a perception of arrival.

Dynamic arrival

We now consider the impact of short-duration, contrasting dynamic events such as the *dynamic punctuation* accent used in C2. Several participants felt strongly that this accent was a marker of some description; speculating it was a point of arrival, a signal to change direction, or the discovery of something. Participants described these accents using words such as *"spot"* and *"point",* which suggest small localized spaces. These descriptions also reflect the musical character of the accents (a short musical event of a three second duration), distinct from the other components that continued to sound until a transition to another zone transpired. *Dynamic punctuation* may not resolve or fade to an end, so listeners may not feel a sense of ultimate arrival, but instead may be alerted to their proximity to a point of interest.

Containment

The *container* image schema was revealed to be a relatively dominant feature of the music compositions.

Mapping music onto spatial structure

The *container* metaphor we proposed for timbre in C4 appeared appropriate. Participants acknowledged the changing instrumental timbres, but on the whole did not feel they inferred spatial motion or progression. Nonetheless, some participants 'mapped out' the zones in response to the timbres heard, building a kind of spatial map of the composition's musical structure. This was also evident with C1 and less so in C2. We observed participants revisiting spaces and testing out zone boundaries, while the interview transcripts reveal the music sections were discussed as *"regions"*, *"areas"* and *"places"*, language that indicates a container metaphor.

The impact of silence

The impact of silence on participant behavior turned out to be particularly important. We noted three distinct behavioral responses to encountering silence: alteration of heading to re-discover music playback; termination of task and a kind of incremental dissolution of task engagement where participants stopped after encountering silence several times. Some re-engaged when confronted with silence, others interpreted the fade out as a signal for the destination and others repeatedly attempted to re-engage, but experienced a loss of momentum in response to the interruptions. What we do observe from all these behavioural traits is a process of containment. While music playback is active, participants were engaged with the task. When not active, disengagement occurred. The findings do not suggest why some participants chose to stop and why some chose to re-engage, and this is an issue we will return to. Here the music functions as a *container of the experience*. The notion of the musical container reflects Michael Bull's work on how iPod users contain and mediate their spatial experiences via personalised mobile listening [2].

It is worth returning to the findings in C3 to further explore how containment is functioning here. With this composition the music did not appear to function well as a *container of the experience*. Participant transcripts reveal a picture of detachment from the spatial experience, as the repetitive nature of the music offered no purchase for 'mapping' and creating a spatialized model of the composition's musical structure. We suggest therefore, that in order for music to function as the *container of the experience*, regular, perceptible musical changes are required to support the formation of attachments between the structure of the music and the physical space.

Walking behaviour

The statistical difference in walking speed observed on C3 may have been as a result of C3's faster tempo (C1 = 60bpm, C2 = 90bpm, C3 = 120bpm, C4 = 54bpm), which references prior research on the synchronisation of physical movement to tempi [20]. We would expect therefore, C2's mean walking speed to be placed centrally between C1 & C3 as was its tempo (90bpm), but this was not observed. To support a robust analysis and discussion on this theme a controlled experimental setting would have been required. We also noted participants engaging in marked changes of direction whilst on task, which prompted an analysis of direction changes in response to musical changes (transitions between zones), but no apparent systematic correlation was found.

IMPLICATIONS FOR COMPOSING MOBILE MUSIC

The final section of our paper considers the implications of our study for the composition of mobile musical soundtracks. These take the form of a series of six recommendations for how to employ musical structures when trying to shape spatial exploration, followed by a simple framework to guide the mapping of musical structures to the spatial locales. Given the exploratory nature of our study, these are tentative recommendations at this stage. Indeed, they might be seen as questions for further studies, as much as guidelines for practice.

Six principles for composing mobile music

Based on the discussion above, we offer six principles to guide the composition of mobile soundtracks:

1. Music should sound consistently. Regular and perceptible adaptations are required to maintain a user's engagement with the environment.
2. In contrast silence is effective for marking ultimate arrival or for forcing disengagement.
3. Timbre, different densities of instrumental texture and to a lesser extent harmony, can be used to characterize different spatial regions. They might, for example, demarcate sets of exhibits or locales in game play.
4. Dynamic Punctuation is effective when wanting to mark a specific location: such as points of arrival or a passing point, object or event of interest.
5. Intensity contours such as a crescendo or building textures, can be applied to influence motion towards or away. However, they should be followed by a point of arrival or release, if they are to be effective: these could be positioned on the approach or withdrawal from points of arrival, or entry into regions of different activity, mood, or function.
6. Harmonic resolution (to the tonic chord) can powerfully convey an impression of arrival.

A framework for musical/spatial attachment

While the six principles above speak to the general potential role of key elements of musical structure in a spatial experience, there is a further specific issue that the composer will need to address. This concerns how to best map these musical structures onto a set of spatial zones (of the kind utilised in the study above). While not all locative experiences need to be structured around sets of discrete zones (or locales or regions as they are sometimes called), this remains the most common approach to designing locative media experiences. It is certainly an approach that has been embedded into several authoring tools. Hull *et al* [12], for example, describe the *Mscape* tool that enables designers to author locative experiences by overlaying different sized regions onto a map and then associating these with scripted events such as triggering the playback of different media when users enter or leave them. Flintham describes how artists used a variant of this approach called *colourmaps,* to create a locative clue trail for a mobile performance by painting different regions onto a map [8]. A notable and interesting feature of their approach was that they created a bounding border region that marked the outer edge of the experience where they tried to encourage participants to turn around and head back the other way.

Our earlier discussion leads us to propose a simple framework for mapping musical structure onto these kinds of spatial structures. Our framework consists of three levels of spatial structure as shown in Figure 6. The first and outermost is global, marking the outer boundary of an experience (like the bounding region in Flintham's *colourmaps* [8]). Next is regional, which defines the zones, regions or locales of the kind found in *Mscape*, *colourmaps*, our own study, and many other locative experiences. The final and innermost level is local, consisting of particular points of interest, for example destinations and specific features of the environment.

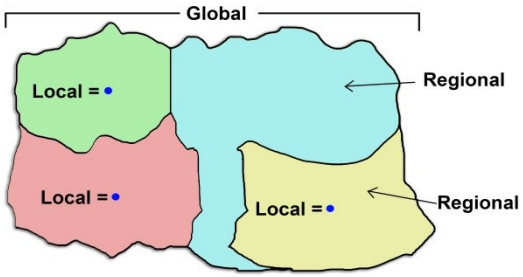


Figure 6: The Attachment Model

Based on our discussion, we propose a three-layered notion of *attachment* between different musical structures and these three levels of spatial structure. Our discussion of the role of silence (embodied in the composing principles 1 and 2 above) suggests that this can act as *container of the experience* at the global level. Variations in timbre, intensity and harmonic progression might then be mapped onto the regional structure, with the choice perhaps depending on whether the intention is to reveal a more static sense of this structure (timbre) or to more strongly suggest a sense of journey through it (harmony and dynamic intensity). Finally, dynamic punctuation and possibly harmonic resolution might be associated with the local levels of this structure, to signify arrival at particular points of interest.

At this point it is worth returning to the related work on sound navigation systems, which use auditory spatialization techniques [6]. We can foresee opportunities for these techniques to integrate with, and supplement, our composing principles to further enrich a composition framework for mobile experiences, primarily in terms of guidance. For example, the application of stereo panning to indicate orientation would complement the use of harmonic motion and dynamic contours, in guiding a listener's approach towards a point of interest. This identifies a theme for future work.

We suggest that this three-layer hierarchical structure, while simple offers a general framework for mapping key musical features such as silence, timbre, dynamics and harmony onto the kinds of spatial structures that are commonly seen in contemporary authoring tools for locative media.

CONCLUSION

The growing interest in mobile musical experiences – both in their own right and as the soundtracks for other experiences such as guides, tours and games – has motivated our exploration of the relationship between musical structure and spatial experience. Unlike previous research into the use of sound for navigation that has tended to focus on low-level musical features such as spatialisation, our exploration has focused on higher-level musical structures with which composers routinely work, namely harmony, melody, timbre and dynamics.

This has been an exploratory study, designed to tease out potentially interesting relationships between musical structure and spatial structure so as to ultimately provide guidance to composers. This initial study suggests that there are complex relationships at play that will certainly require further research to unpack. It does suggest however, that while people may potentially interpret music in many ways, at least in an open-ended scenario, that they are often able to follow changes in compositional structure that then influence their spatial experience. This has led us to propose some tentative principles for the use of dynamics, melody, harmony, timbre and also silence in composing mobile music, and also to suggest a three-lay framework of spatial attachment. Future work will focus on further mapping these relationships, as well as exploring their use in 'real world' scenarios such as tours and games.

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REFERENCES

1. BlueBrain, http://bluebrainmusic. blogspot.co.uk/search?updated-max=2012-01-02T09:27:00-08:00&max-results=7
2. Bull, M., Personal stereos and the aural reconfiguration of representational space, in Sally Munt (ed.) TechnoSpaces: inside the new media, London: Continuum, 2001
3. Brower, C. A., Cognitive Theory of Musical Meaning. *Journal of Music Theory*, 44 (2) (2000), 323–379
4. Eitan, Z. and Granot R. Y., How Music Moves: Musical Parameters and Listeners' Images of Motion. *Music Perceptio*n, 23 (3) (2006), 221–247
5. Elliott, G. T. & Tomlinson, B., Personal Soundtrack: context-aware playlists that adapt to user pace. In *CHI'06 extended abstracts*. ACM (2006), 7*36-741*
6. *Etter, R., & Spe*cht, M., Melodious walkabout-implicit navigation with contextualized personal audio contents. In *Adjunct proc. of the third international conference on pervasive computing,* 191 (204) (2005)
7. Fencott, R., and Byran-Kinns, N., Sensory Threads: Sonifying imperceptible phenomena in the wild. In *Proc. of the 6th Sound and Music Computing Conference,* 2009
8. Flintham, M., Painting the town red: configuring location-based games by colouring maps. In *Proc. of ACE 2005.* ACM, 2005, 9-18
9. Harris, Y., Taking Soundings – Investigating Coastal Navigations and Orientations in Sound. In *Proc. of the 4th Mobile Music Workshop*, 2007
10. Heuten, W., Wichmann, D., Boll, S., Interactive 3D Sonification for the Exploration of City Maps. In *NordiCHI,* 2006, 155–164
11. Huerta, R., *A thousand and one ways of listening to music on your 'smartphone'.* http://cultura.elpais.com/cultura/2012/12/03/actualidad/1354529812_286215.html
12. Hull, R., Clayton, C., Melamed, T., Rapid authoring of mediascapes. *Proceedings of Ubicomp,* 2004. Springer, 125–142
13. Karageorghis, C. I. & Terry, P. C., The psychological, psychophysical, and ergogenic effects of music in sport: A review and synthesis. In Bateman, A., Bale, J., (Ed(s)), Sporting sounds: Relationships Between Sport and Music, 1 (2008), 13-36
14. Kohn, D. & Eitan, Z., Musical Parameters and Children's Movement Responses. In *Proc. of the 7th Triennial Conference of European Society for the Cognitive Sciences of Music (ESCOM),* 2009
15. Meyer, L.B., *Emotion and Meaning in Music.* University of Chicago Press, 1956
16. Nemirovsky, P. *Aesthetic forms of expression as information delivery units*. Available from: http: //www.web.media.mit.edu/~pauln/research/ guideshoes/thesis/Thesis.pdf
17. Ratner, G., *The Musical Experience: Sound, Movement, and Arrival.* W. H. Freeman, 1983
18. Reality Jockey Ltd. *The Sonic Experiences of the 21st Century*. http://rjdj.me
19. Spotisquare, http://www.spotisquare.com
20. Styns, F., Van Noorden, L., Moelants, D. and Leman, M., Walking on music. *Human Movement Science*, 26 (2007), 769-785
21. Tanaka, A., Visceral Mobile Music Systems. In: Adams, R., Gibson, S. and Arisona, S. M. (Eds.), *DAW/IF 2006/2007, CCIS 7, pp. 155–170, 2008*
22. Wilkie, K., Holland, S., & Mulholland, P. What can the language of music tell us about Music Interaction Design? *Computer Music Journal CMJ* 34(4) (2010)