

Datascaping: Data Sonification as a Narrative Device in Soundscape Composition

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ABSTRACT

Soundscape composition is an art form that has grown from acoustic ecology and soundscape studies. Current practices foster a wide range of approaches, from the educational and documentary function of the world soundscape project (WSP) to the creation of imaginary sonic worlds supported by theories of acousmatic and electroacoustic music.

Sonification is the process of rendering audio in response to data, and is often used in scenarios where visual representations of data are impractical. The field of auditory display has grown in isolation to soundscape composition, however fosters conceptual similarities in its representation of information in sonic form.

This paper investigates the use of data sonification as a narrative tool in soundscape composition. A soundscape has been created using traditional concrete sounds (fixed media recorded sound objects), augmented with sonified real-time elements. An online survey and listening experiment was conducted, which asked participants to rate the soundscape on its ability to communicate specific detail with regard to environmental and social elements contained within. Research data collected shows a strong ability in participants to decode and comprehend additional layers of narrative information communicated through the soundscape.

CCS CONCEPTS

• **Human-centered computing** → **Auditory feedback; Empirical studies in HCI**; • **Applied computing** → **Sound and music computing**;

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KEYWORDS

soundscape composition, data sonification, acoustic ecology, generative music

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1 INTRODUCTION

Our understanding of the world has always in part been mediated through sound and vibration. The fields of acoustic ecology [11], soundscape studies [14], soundscape composition [22] and auditory display [4] all rely on our ability to extract spatial and contextual information from the sonic world around us. A key factor in these subject areas is the notion of communication and the depiction of environmental, physical and/or social narrative through sound. Although some degree of commonality, and at times influence, can be found between this diverse range of fields and practices, distinct lines of thought and approaches grow uniquely from each.

This paper is set within the framework of soundscape composition, and seeks to unify the initial intention of acoustic ecology, the more recent (and wide ranging) practices of soundscape composition, and techniques for accurate data sonification found within auditory display. A cross-modal approach has been developed specifically for this paper and the term ‘Datascaping’ is introduced to describe the use of real-time data as a medium in soundscape composition. The paper presents an exploratory case study and body of research investigating the use of ‘Datascaping’ as a narrative tool in soundscape composition.

As part of the study, a generative system has been designed to dynamically render sonification of real-time data sourced from the transport for London (TfL) Application Programming Interface (API). The system reads and passes train location and London Oyster Card data (MIFARE prepaid contactless RFID travel cards) through a predefined sound

mapping process to create a ‘soundscape’ portraying real-time habitation levels of selected lines and stations of the London underground. The sound mapping process fosters the use of conventional Western harmonic devices, in combination with mathematical systems to distribute notes in time based on the system’s input signals. The system has been used to produce a real-time soundscape composition, which has been presented to a group of participants to assess the suitability of the sound mappings in relation to the comprehension of intended narrative. The ‘Biorhythms - London’ soundscape uses a combination of traditional soundscape techniques augmented with real-time data sonification to portray additional layers of narrative, often hidden from both the eye and ear.

This paper demonstrates proof of concept and publishes initial qualitative data in relation to the theme. Areas of further research and development are discussed, as well as questions that have arisen from the process.

2 RELATED WORKS

The soundscape

The concept of soundscape grew from the mid 1960s and the seminal works and writings of R. Murray Schafer [11]. The work of the world soundscape project (WSP) at Simon Fraser University initially took an educational focus, seeking to document and archive the evolving sounds of the analogue world. Set within a framework of acoustic ecology, soundscape studies resisted firm definition, and through exposure to artists and musicians, the practice of soundscape composition grew, contextualised within both acousmatic [6] and electroacoustic [16] traditions. Truax [15], Westerkamp [22] and Drever [6] reflect on this lack of definition, reviewing the range of approaches and presenting possible unifying theories. Truax [14] succinctly divides the characteristics of soundscape composition into four key points:

“(a) listener recognisability of the source material is maintained, even if it subsequently undergoes transformation; (b) the listener’s knowledge of the environmental and psychological context of the soundscape material is invoked and encouraged to complete the network of meanings ascribed to the music; (c) the composer’s knowledge of the environmental and psychological context of the soundscape material is allowed to influence the shape of the composition at every level, and ultimately the composition is inseparable from some or all of those aspects of reality; and ideally, (d) the work enhances our understanding of the world, and its influence carries over into everyday perceptual habits.”

Westerkamp [22] suggests:

“once we have accepted the acoustic ecology arena as the basis from which soundscape composition emerges, one could perhaps say that its essence is the artistic, sonic transmission of meanings about place, time, environment and listening perception.”

More recently, both Drever [6] and Samuels [10] review the potential for soundscape composition to foster ethnographic qualities, and for it to feature as a new tool in a redefined ethnographic process:

“ethnography can offer the practice of soundscape composition ways to move forward in a relevant and socially functional way, which reflects the complexities of today’s cultures.” [6]

Ethnography is often challenged by the questions of translation and documentation, and the effect of these processes on inherent and subsequent meaning. The use of data can potentially be seen as a raw and truth giving medium, providing direct reflection without translation.

Generative Soundscapes

Within the field of soundscape composition, numerous generative approaches have been undertaken, several of which approach the use of data in some form or another. Birchfield et al. [2] and Thorogood et al. [12] use semantic data and natural language processing to search and select suitable audio files for a generative soundscape. However ultimately, the compositional processes are user driven and fail to harness the data for any narrative function, thus limiting its ethnographic reach. Closer to the approach taken in this paper, Birchfield et al. [3] use generative techniques to communicate a personal narrative through the collection and annotation of media files relating to an individual’s lived experience. Although conceptually similar to the “datascaping” approach, the data are subjectively derived and present more of a personal narrative than an objective truth. The work may also have been limited by the availability of real-time data through web-based APIs at the time of publication (2005) and suffers from a very low sample rate, attempting to communicate the experiences of a day in three or four samples. The development of the data age now provides opportunities for high sample rates, which may better support the usage of data as effective narrative device.

Data Sonification and Auditory Display

Data sonification is the process of rendering audio in response to data, often to facilitate interaction where visual displays are impractical [23]. As a field it focuses on human computer interaction (HCI) principles, and develops processes to accurately communicate information to a user,

without a direct focus on art, music, composition or ethnography. In the development of this paper, techniques and processes from the field of data sonification and auditory display have been reviewed, analysed and implemented to provide a platform for ‘Datascaping’.

Zhao [26] [25] and Nikerson et al. [9] both work with the sonification of visual geographic data such as maps. Although relevant to some aspects of the current research, their work primarily focuses on an audio information seeking principle (AISP) which enables users to navigate large datasets aurally, and in turn investigates a much higher-level interaction process.

Several studies investigate the use of soundscapes as a tool in data sonification, however approach the problem to achieve more effective data sonification, as opposed to facilitating more effective narrative detail in soundscape composition. Vickers [19] suggests taking a soundscape approach to auditory display can reduce fatigue in repeated listening, where Mauney and Walker [8] [7] conclude natural sounds to be calming and unobtrusive in a working environment. Wolf et al. [23] propose a model for a data-driven sonification using soundscapes, claiming it enables users to work with familiar sounds, however highlight the complexity and limitations in manipulating concrete sound objects. Although relevant in relation to systems and methods, the context to these works is firmly set within the field of auditory display, and misses the culture and context of soundscape studies, acoustic ecology, and ethnography.

Closer in concept to the current paper, Vickers [18] discusses the communication of narrative within the context of sonification, however limits his research to non-verbal social communication.

Datascaping

Although, to the best of our knowledge, the term ‘datascaping’ is pioneered in this paper for the first time, very few ideas grow in isolation and several key themes and elements of prior research have been influential in solidifying a foundation for the work. Walker et al. [20] presents an effective system for the creation of real-time soundscapes, focussing on the representation of fish within an aquatic system. Many narrative details are communicated such as type, colour, size, location, speed, and direction. Also of relevance is a study by Boren et al. [5], which seeks to augment a concrete binaural soundscape with virtual elements extracted in real-time from online sources such as Yelp and Twitter.

At the heart of datascaping is the desire to use a framework of data sonification, and the aesthetics of acousmatic and electroacoustic music to increase the ethnographic reach of soundscape composition and to achieve one of the initial desires of the world soundscape project (WSP) to document

our sonic world.

“A contemporary ethnographic approach to soundscape composition may require that the composer displace authorship of the work, engaging in a collaborative process, facilitating the local inhabitants to speak for themselves in an interplay of voices, of positioned utterances.” [6]

The collaborative nature of data, through the very essence of the medium, enforces this displacement of authorship and firmly places ownership and representation back into the hands of cultures, societies and peoples. This notation of implicit creative participation will be discussed in more detail below.

Implicit Creative Participation in Interactive Art Using Data as Proxy

One of the motivations behind participatory art is to bridge the gap between audiences and artists by blurring the roles of creators and receivers [17]. Recent studies in interactive digital arts have proposed new technical and aesthetic principles enabling the creative participation of audiences in the production and reception of art works based on digital information and communication technology (ICT). [24] presents a review of such approaches in the case of participatory live music performance.

When data used in the production of an art work describe or correlate with some human activity or state (e.g. data related to behavior, sentiment, affect, etc.), we argue that the people represented by the data hold a participatory role in the realisation of the art work. Following this principle, data may be seen as a “proxy”¹ for human intervention in the production of an art work. We qualify this type of participation as indirect and implicit, given the layers that exist between the source and the produced result and that what is entailed is not necessarily known from the participants. Hence, the “datascaping” soundscape generation approach advanced in this paper can be thought of as a way to create an implicit, indirectly intentional, and anonymous form of participation for the people the data originate from. Such data-based participatory art can be either asynchronous, given that data can be recorded, stored and reused later, or (quasi) real-time through the use of interconnected information networks [1, 21].

3 DESIGN PROCESS

The aim of ‘Biorythms’ is to augment the concrete reality of a traditional soundscape with a layer of additional narrative information conveyed through the use of real-time data sonification. The soundscape is orientated on the London

¹intermediary, in the ICT sense.

underground and uses real-time data from the Transport for London (TfL) API. As the ongoing artistic focus of the Biorhythms project is to explore the human/machine hybrid we know as ‘city’, the current implementation focuses on human/machine population density, seeking to communicate movement and population on the underground throughout the day.

The soundscape can be auditioned here: <http://goo.gl/Pkr9PC>

The following sections outline the stages of the sonification process.

Data Collection and Sanitation

We developed a Java application which accesses train location data in real-time from the TfL API. The data streams are processed to extract unique train identifiers (IDs) and locations. Each train location is plotted in two dimensions and superimposed onto the commonly known London underground map. The resulting two-dimensional X/Y coordinates are used in a range of sonification processes discussed in more detail below.

Sonification - Pitch and Dynamics

The X/Y coordinates of each train are scaled to a Midi range (0-127) using Max/MSP and added to an array of possible musical events for their respective underground line. These events are then randomly selected from the array on a note-by-note basis with a dynamically evolving rhythmical process (discussed in the next section). The processes enable each line to create a unique scale and dynamic range based on its physical geometry.

Each line is associated to and “played” by a discrete instrument, enabling communication of multiple factors within the melody. The example used in this paper takes a tonal approach to the soundscape, and note events have been quantized to a minor pentatonic scale in C. This particular choice was influenced by wind chime tunings, which we believe provide an effective and culturally recognized auditory barometer for the communication of narrative information.

The dynamic choices for each note are linked to the levels of human population, derived from travel card entry, exit and interchange data. As more people travel, greater population density is highlighted on specific lines and in specific locations through dynamic fluctuation in the musical parts.

Sonification - Rhythm

To generate the rhythm for each musical part, the theory of Euclidean rhythms has been used [13], which implements Euclid’s algorithm in a musical context to derive a range of different rhythmical metres. The dominant factor in the

algorithm is provided by the number of stations on each line (Victoria: 16, Central: 49, Jubilee: 27, and Circle: 27), personalising the rhythms of each line and providing a characteristic range of time signatures and potential polyrhythms. The subdominant factor in the algorithm is the scaled real-time number of passengers using the line.

In order to capture the rate and flow of people around the underground network, travel card entry, exit and interchange data is used, providing a good estimation of current habitation levels. As habitation increases the divisions of the bar increase, thus representing changes in habitation in rhythmic form.

Sonification - Structure and Arrangement

In order to portray a day (6AM-12PM) in a short soundscape (as discussed below), an average of daily travel card entries, exits and interchanges at Victoria station for 2016 has been used (see Figure 1). Although the system operates in real-time, a set excerpt length of five minutes was established to aid dissemination of material for review and to regulate the experiences of each participant. The data provide an effective indication of movement throughout the day.

As well as providing a constantly modulating source for rhythmical development, the data are also used to control the level of each instrument (or train line) dynamically. As habitation of a certain line increases, as does the pace of the notes in the melody and its level. The total habitation dataset is used to control the level of the North and South bound Victoria line melodies, providing a direct link between the level of the two key musical parts and movement throughout the day. The dataset for the interchange rate is used to attenuate the volumes of the adjoining lines (Central and Jubilee). The entry and exit datasets are used to dynamically adjust the stereo position of the four key instruments. The bass part (Circle line) remains static, enforcing its control of the heartbeat of the city.

The resulting Midi data are sent in real-time to the digital audio workstation Apple Logic Pro, where it is complemented with a more traditional approach to concrete sound within the soundscape.

Concrete Sounds

The concrete elements of the soundscape were manually placed over the five minutes and follow a rough pattern of departure, travel and arrival. It is intended that these concrete elements will promote a traditional reflection of soundscape composition with which to compare and contrast the ‘datasaped’ elements.

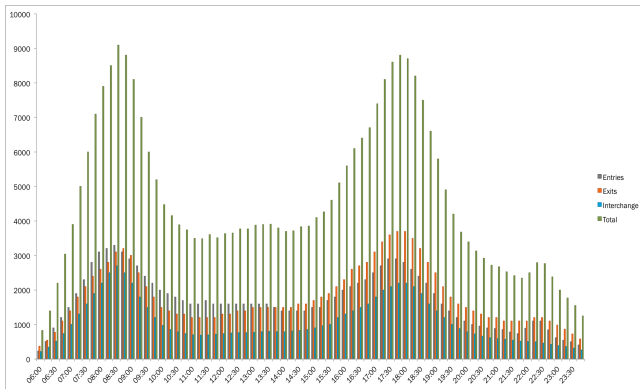


Figure 1: Graphed retrospective Oyster data (2016)

4 RESULTS

Survey data was collected from a group of 11 Media and Arts Technology doctoral research students and lecturers at Queen Mary University of London. All participants had some knowledge and understanding of both soundscape composition and data sonification, with some subject experts represented. The full survey and soundscape can be accessed here: <http://goo.gl/L6cP87>

The survey started with three single/multiple choice questions which were completed without prior knowledge of the soundscape compositional processes:

- Question 1 (multiple choice) probed for the detection of change(s) in pace within the soundscape and their timings. At this point, no information had been provided in regard to the compositional processes so as a not to guide or lead responses.
- Question 2 (single choice) sought to investigate the source of this perceived change in pace. Participants were able to choose between the recorded sounds, the instrumental melodies, both sources or neither source.
- Question 3 (multiple choice) focused on the musical (sonified) elements and sought to establish key communicators of the perceived change in pace. Participants were able to choose between pitch, rhythm, tempo, timbre, texture, or a combination of these.

The following six single choice questions were completed after reading a description of the compositional processes, enabling participants to rationalize their listening experience:

- Question 4 sought to investigate how well the soundscape communicated human/social factors.
- Question 5 sought to investigate how effective real-time data was at adding narrative to the soundscape.
- Question 6 sought to investigate how real-time data aided interpretation of the soundscape.

- Question 7 sought to investigate the use of data sonification as a viable tool to document social factors such as habitation.
- Question 8 sought to investigate the use of data sonification as viable tool to document environmental factors such as temperature, humidity, UV radiation and pollution.
- Question 9 sought to investigate the use of data sonification as viable tool to document personal factors such as happiness, health, socio-economics and identity.

The survey results are presented in Figures 2 and 3 where bar charts indicate the number of participants who selected the associated question topics.

5 DISCUSSION

Qualitative analysis of survey question 1 (Figure 2a) indicates that the participants perceived several changes in pace throughout the soundscape. In Figure 2b, the participants' responses are superimposed with the actual travel card data. Participants' perception appears to correlate positively with habitation levels as expressed by travel card data usage. It should be noted this data was collected with no prior knowledge of the compositional methods.

The results of survey question 2 (Figure 2c) provides a good indication that the concrete sounds used in the soundscape are both relevant and important in participants' expectation, with over half the participants claiming both the recorded sounds and instrumental melodies were effective at communicating change. As a point of future research, the balance of concrete and sonified elements should be varied to establish a greater understanding of their effect in both isolation and combination.

The results of survey question 3 (Figure 2d) evidence the clear perception of 'rhythm' and 'texture' as communicating factors in the soundscape, which correlates well with the actual compositional processes implemented. Pitch was clearly present within the soundscape, however it did not play a role in communicating the change of pace. This is reflected well, with only one out of 11 participants claiming pitch to be a contributing factor. As the compositional processes were not communicated to participants before answering the questions, the results clearly highlight effective and perceptive narrative communication.

The results of survey question 4 (Figure 3a) confirmed that the soundscape communicated narrative elements linked to human or social factors, with 9 out of 11 participants agreeing to some degree (from 'A little' to 'Very'). Of the possible responses, participants were cautious in their estimation of the degree of effect, however the results of questions 1 to 3 evidence that they were potentially better at decoding the narrative than they expected. Considering no instruction was given or prior experience obtained, we feel the caution

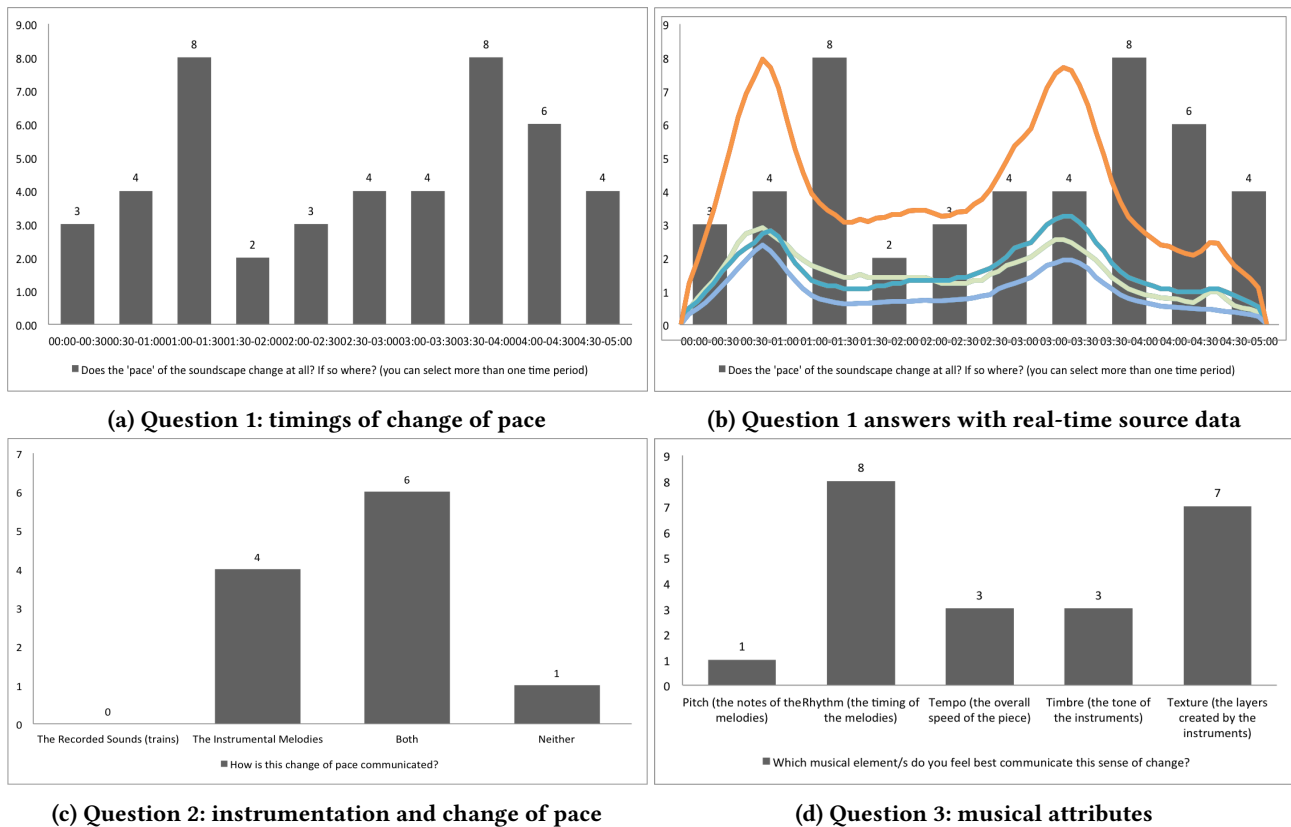


Figure 2: Survey Results - Questions 1 to 3

is understandable, however further testing will be designed to assess the subsequent learnability of the system mappings.

The theme of real-time data communicating narrative elements within the soundscape was well received, with 10 out of 11 participants indicating its effectiveness to some degree in survey question 5 (Figure 3b). Eight out of 10 participants indicated the incorporation of real-time data actually aided their interpretation of the soundscape in their answers to survey question 6, as shown in Figure 3c (one participant chose not to answer this question).

Survey questions 7, 8, and 9 (Figures 3d to 3f) provide clear indication that all 11 participants felt the real-time data were a viable solution to communicating a range of additional dimensions of narrative within the soundscape. However, further investigations are needed to cross-validate such self-reports with user experience measures.

6 CONCLUSION

The Biorhythms soundscape and the research data it has helped to collect, demonstrate that data sonification can be a viable and successful tool in the communication of additional narrative within soundscape composition. The work

pioneers a new approach to the field and the current research suggests some credibility in the concept of ‘datascaping’. As a relatively new permutation to existing theory, further work and research is needed to formalise an approach and solidify a greater theoretical background.

Although the outcomes of this study have been successful, several areas require further investigation. The balance of concrete vs. sonified elements is still a dependent variable. As the results of survey question 2 suggest, six out of 11 participants perceived some narrative value from the recorded sounds, separating and investigating the effect of each variable is essential. In the current study, only one dimension of additional narrative was presented (habitation over time). Additional work will be needed to assess the strength of these techniques with multiple dimensions. The current study implements a Western tonal system for the sonified elements. Further research is needed to investigate other possible tonal/non-tonal solutions and evaluate their relevance. Throughout the completion of this paper, the theme of soundscape composition as an ethnographic tool has become more and more influential. Notions of ethnography should inform future methodology.

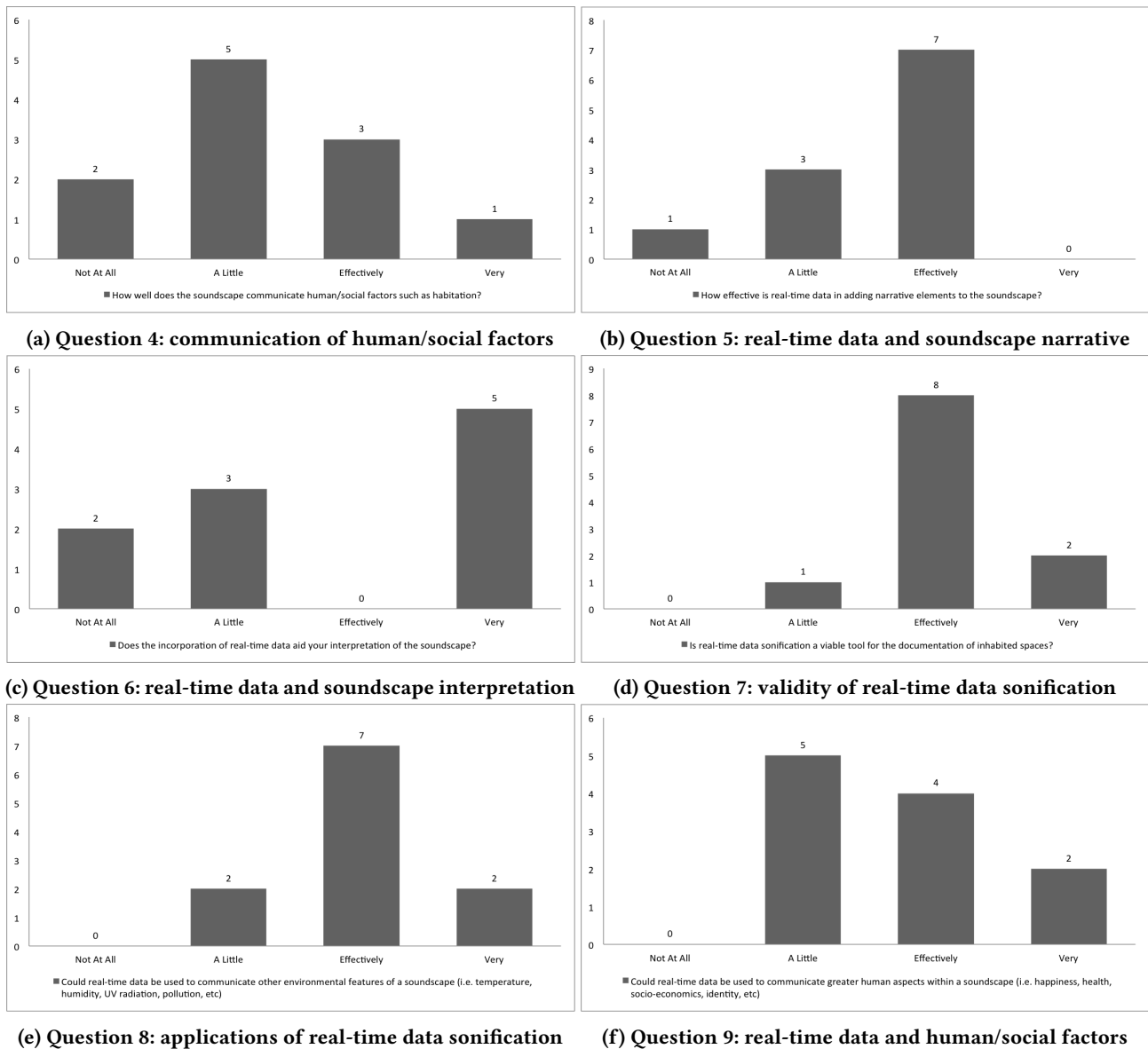


Figure 3: Survey Results - Questions 4 to 9

To conclude, the data collected support the hypothesis of the paper, providing good initial evidence that data sonification is an effective narrative tool in soundscape composition.

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