Exploring the Untapped Potential of Sound Maps

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1. Introduction

Sound maps represent the sound of a special territory, they consist of a map and located soundscapes. A soundscape is not only a sonic environment, "*like a landscape, a soundscape is simultaneously a physical environment and a way of perceiving that environment*"[1]. A first research has shown that most sound maps

[1] Thompson, Emily: The Soundscape of Modernity. Architectural Acoustics and the Culture of Listening in America. 1900-1933, Cambridge/London, 2002, p. 2. Available online: http://pzacad.pitzer.edu/~mma/teaching/MS115/readings/thompson.pdf (last accessed: 23 February 2017).

are visualised in the same way and do not invite further exploration. The visualisation of sound itself also opens up more challenges. Our ideas, problems and subsequent solutions have led to the following three research questions and a prototype of a new sound map visualisation, which are both discussed in this paper:

(1) How can time-based soundfiles be visualised in such a way that the information they contain becomes clear at once?

(2) How can the existing metadata and associated media (photographs, texts) be embedded efficiently and support easy search as well as serendipitous exploration?

(3) What role do subjectivity and objectivity play in the visualisation, when the data is contributed by the public and not curated?

In this field there seem to be no further research that take a look onto a problem solving of these questions, which makes our research relevant.

2. Related work

Firenze Sound Map[2] is a collective collection representing the Florentine soundscape from an emotional perspective. The project, which was launched in 2009 by Antonella Radicchi, features audio recordings, pictures and user feedback located in a map of the city of Florence. The collection contains 67 datasets that were shared by citizens and tourists.

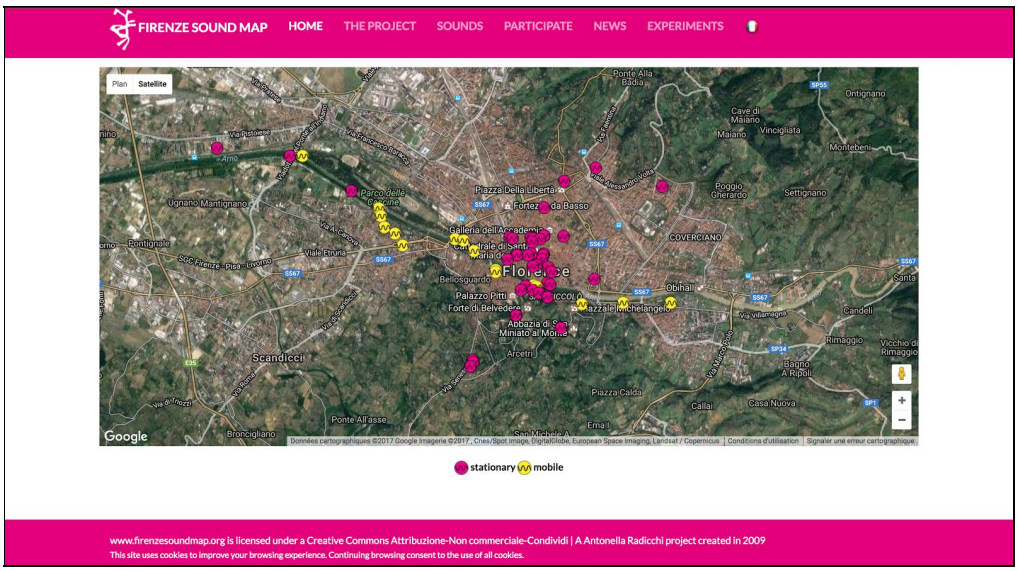

Fig. 1: The *Firenze Sound Map* website, showing the 67 sound recordings of Florence.

[2] Radicchi, Antonella / Firenze Sound Map (2009/2017): Firenze Sound Map.
URL: http://www.firenzesoundmap.org/eng/default.asp (last accessed: 23 February 2017).

The research of the group has shown that there are a lot of sound maps from different cities, which all include similar information, such as location, sound recordings and images, but show no unique or only limited exploration possibilities. Outstanding projects are *favourite sounds*[3] where people's favourite soundscapes are located and the content is described through tag words. *Nature Sound MAP*[4] in contrast concentrates, as the title says, on sounds from nature. This map allows to dive into soundscapes that can't be heard in everyday life, e.g. animals singing while a monsoon storm passes. *Sound Around You*[5] by the University of Salford Manchester uses different ranking categories to describe the location and soundscape quality and soundscape pleasantness[6], further it is possible to name positive or negative sounds. Already in the 1970s R. Murray Schafer visualised soundscapes in his *Five Village Soundscapes Project*[7], symbols were used to describe sound information. The *World Soundscape Project*, a small group of researchers led by R. Murray Schafer, visited different cities and villages to document their soundscapes[8]. The F*ive Village Soundscapes Project* resulted in comic-like sketches depicting soundscapes in descriptive words and symbols indicating the direction or area of the sound. Even notes on a musical scale were included.

A different kind of map representing acoustic environments are noise maps. According to the Environmental Noise Directive (END or Directive 2002/49/EC) of the European Parliament and of the Council of the EU strategic noise maps are "*map[s] designed for the global assessment of noise exposure in a given area due to different noise sources or for overall predictions for such an area;*"[9]. Their purpose is

[3] Cusack, Peter / Favourite Sounds (2012): Favourite Sounds. URL: http://www.favouritesounds.org/ (last accessed: 16 February 2017).
[4] Anderson, Marc / Nature Sound Map (2013): Nature Sound Map. URL: http://www.naturesoundmap.com/ (last accessed: 16 February 2017).
[5] Mydlarz, Charly / University of Salford Manchester (2011): Sound Around You. URL: http://www.soundaroundyou.com/ (last accessed: 16 February 2017).
[6] Mydlarz, Charly; Drumm, Ian & Cox, Trevor (2011): Application of novel techniques for the investigation of human relationships with soundscapes. Conference paper from Inter Noise, 4-7 September 2011, Osaka, Japan, p. 4. URL: http://www.soundaroundyou.com/images/Internoise_2011.pdf (last accessed: 23 February 2017).
[7] Schafer, R. Murray (1975): Five Village Soundscapes. URL: http://www.sfu.ca/~truax/FVS/fvs.html (last accessed: 17 February 2017).
[8] Canova, Andrea Zarza (2013): Five European Villages. URL: http://blogs.bl.uk/sound-and-vision/2013/07/five-european-villages.html (last accessed: 23 February 2017).
[9] European Parliament and Council of the European Union (2002): Directive 2002/49/EC. Definitions – Strategic Noise Map. URL: http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32002L0049&from=EN (last accessed: 17 February 2017).

to display noise levels, not necessarily identifying the noise sources or kinds of noises, and they are not intended to display recordings. Thus, noise maps do not contain sound files but are more so comparable to heat maps in that they indicate the sound level "pollution" in a specified area during a specific time period. An example such as the *Berlin Lärmkarte*[10] shows that these maps only define the level of noise and do not deal with the "quality" of noise.

Sensory maps chart phenomenons perceived through our senses, such as smell or touch. The *Smellmap Amsterdam*[11] is one example depicting smell through words, symbols and color-coding. One way to map emotions is through emotional geography or emotional cartography, the *Stockport Emotion Map*[12] documents the feelings and memories collected by locals, visitors and individual users on a map and identified five issues of the city[13]. Through drawings, bars and quotes it displays memories such as: "*This area is very empty without the market*".

In the field of sound visualisation, there are very few outstanding projects that allow an analysis or exploration of acoustic data based on content or emotions. The only information that is usually visualized is frequency or amplitude (e.g. pitch or volume). One visualisation called *Dancing Colors* generates the frequency into color and the volume into a position[14]. Another possibility is to generate sound spectrograms e.g. with the *Acousmographe* software[15].

Under use of t-SNE it is possible to show connections between sounds by sorting them with machine learning. The *Infinite Drum Machine*[16] sorts sounds and places them close to one another based on their similarity. Therefore it provides a unique data-driven view of the whole database, allowing further exploration possibilities. Nevertheless, it is still difficult to analyse soundfiles for their content, especially if you work with soundscape recordings that contain lots of sounds playing simultaneously. There is software available that recognizes speech and

[10] Tröger, Julius; Möller, Christopher; Klack, Moritz; Boenke, Max and Wendler, David (22 September 2015): Lärmkarte Berlin. So laut ist es vor ihrer Haustür. In: Berliner Morgenpost. URL: http://interaktiv.morgenpost.de/laermkarte-berlin/(last accessed: 17 February 2017).
[11] McLean, Kate / Sensory Maps (2014/2017): Smellmap: Amsterdam. URL: http://sensorymaps.com/portfolio/smellmap-amsterdam/ (last accessed: 16 February 2017).
[12] Nold, Christian (2007a): Stockport Emotion Map. URL: http://stockport.emotionmap.net/map.htm (last accessed: 16 February 2017).
[13] The issues for the city of Stockport identified through the emotion mapping are: 1. The marginalised history of Stockport 2. The hidden river Mersey 3. Monolithic shopping 4. Semi-Public Space and 5. Isolation of young people. Nold, Christian (2007b): Stockport Emotion Map. Project Background. URL: http://stockport.emotionmap.net/background.htm (last accessed: 16 February 2017).
[14] Oefner, Fabian (2012): Work: Dancing Colors. Project Description. URL: http://fabianoefner.com/?portfolio=dancing-colors (last accessed: 20 February 2017).
[15] Acousmographe software (2014) URL: http://www.inagrm.com/accueil/outils/acousmographe (last accessed: 17 February 2017).
[16] McDonald, Kyle; Tan, Manny & Mann, Yotam (2016): The Infinite Drum Machine. In: A.I. Experiement. URL: https://aiexperiments.withgoogle.com/drum-machine/view/ (last accessed: 16 February 2017).

transcribes it into texts, but for soundscapes there is no option yet. For example, it is still difficult for a computer to make a distinction between a child's laughter and adults chatting in the background. This phenomenon also present in the human perception of sound was described theoretically by Murray Schafer. He divided the sounds of soundscapes into three categories: keynote sounds, signals and soundmarks. *Keynote sounds* are the background of an acoustic environment, often a sound humans are not aware of until it disappears. Different from the keynote sound is the *signal* as a sound in the foreground, such as bells or sirens. Lastly, *soundmarks* are the sounds that are typical for a region and are recognised as particular by a community.

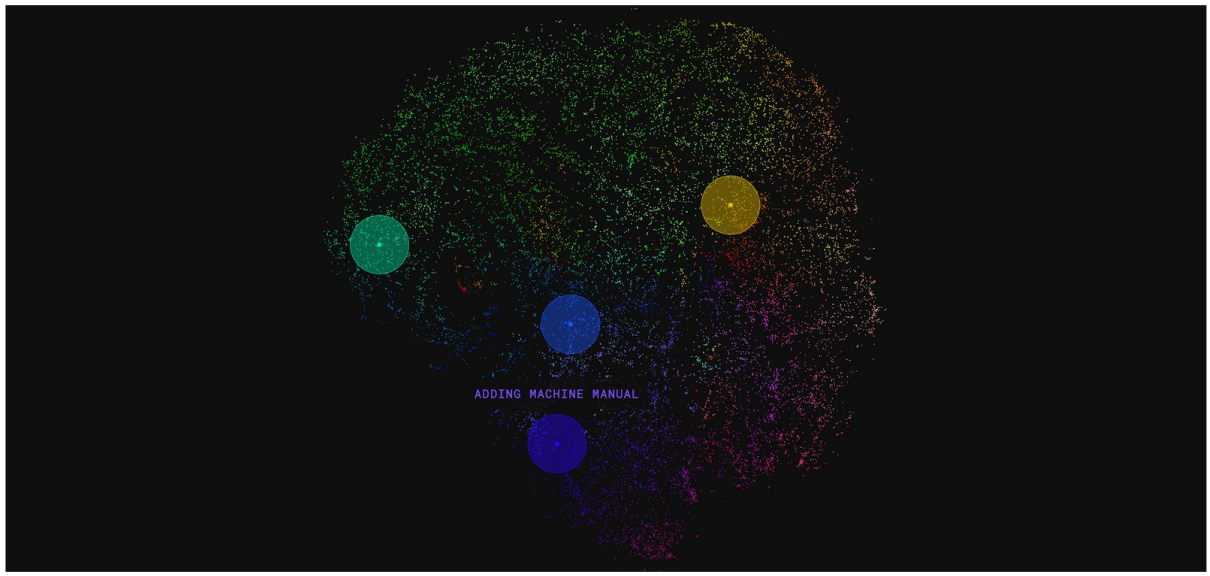

Fig. 2: *The Infinite Drum Machine* shows more than 13'000 sounds using the T-SNE method.

Murray Schafer goes on distinguishing between *Hi-Fi- and Lo-Fi-Soundscapes*. The former is common for rural areas where signals can be easily distinguished from the other sounds and noises. Cities however, suffer from a Lo-Fi-Soundscape which is characterised by a network of sound that swallows signals and makes it difficult to have a spatial perspective on hearing or hear distant sound.[17]

[17] Hannoschöck, Elena (2009): Soundscapes und Lärm. Zur kulturellen Wahrnehmung und Deutung von Klängen. (pp. 37-51) In: Müske, Johannes & Overdick, Thomas (editors) (2009): Vokus. Hafen - Klang - Landschaft. Edition 19/2, Hamburg, pp. 40-41.

More experimental attempts, that diverge from conventional music notation on music sheets, print sound files into 3D-models as in the *Microsonic Landscapes*[18] project or turn data into sound as it was done during the *Specimen Box*[19] project. Furthermore, it is interesting to research how it is possible to show the content of a soundscape visually at once. Time-based media need to be played to recognize the content, which is a criteria that makes it more difficult than working with collections of images. Dealing with intangible content needs different handling. Mostly the data parameters of the sound map are not connected to each other, which prevents further exploration of the city's soundscape. As the *Firenze Sound Map* shows typical metadata of the soundscapes contain, beside the audio recording, the following information,: author, date, daytime, sound source, duration, comment/emotion.
Another issue that sound maps have to deal with is the visualisation of range of soundscapes. Influenced by factors like weather, various surround activities and time the range varies a lot. Sketching this range is not clearly possible, the contributor of the recording would have had to do it during recording and also would have had to check the range from different marks.

Yi-Hsuan Yang and Homer H. Chen examined ranking-based music emotion recognition (MER) and 2D emotion space (2DES). MER is a machine-based music analysis developed to determine the emotions transferred in or through a song using labels and categories to enable content-based retrieval of music. The researchers criticize that MER only offers static categories whose definition varies between individuals and contrast it with 2DES which views emotions "*from a continuous perspective and represent[s] them in a 2D emotion space (2DES) in terms of arousal (how exciting/calming) and valence (how positive/negative), the two basic emotional dimensions found to be most important and universal*"[20]. They define several issues to the rating of emotions: the rating scales might not be "*consistent between and within subjects*"[21]. The emotions are ranked with respect

[18] De J. Escalante, Juan Manuel (2012): Microsonic Landscapes. URL: http://www.realitat.com/microsonic/ (last accessed: 22 February 2017).
[19] The Office for Creative Research (2014): Specimen Box. URL: https://ocr.nyc/user-focused-tools/2014/06/01/specimen-box/ (last accessed: 22 February 2017).
[20] Russell, J.A.: A circumplex model of affect. In: Journal of Personality & Social Psychology, vol. 39, no. 6, pp. 1161–1178 adapted by Yang, Yi-Hsuan and Chen, Homer H. (2009): Music Emotion Ranking. URL: http://www.mirlab.org/conference_papers/International_Conference/ICASSP%202009/pdfs/0001657.pdf (last accessed: 27 January 2017), p.1.
[21] ibid.: p. 1.

to absolute positions not relative to one another. They suggest a comparative approach, i.e. asking which song is more exciting instead of assigning a value to each song. In their research with 602 subjects applying the comparative ranking they find their suggestion to be more successful and satisfying than the automated MER approach.
Scholars such as Gabrielsson[22] or Kivy[23] argued that there is a difference between the emotion felt by the listener and the emotion expressed in the music, this has led to a number of studies discussing the cognitive perception of music and its effect. For our research the relevant factor was the differentiation between expressed, perceived and felt emotion.

When it comes to rating, a very well established system seems to be in place. Very often, users may find themselves being able to select on a scale from 1 to 5, as for example the Amazon star rating suggests. On other platforms, e.g. YouTube a selection between a thumbs up and down is available. As Yang and Chen already suggested the approach of scaling is difficult and relies heavily on perception. This is further backed by the findings of Héctor Martinez and his team that there is an underlying, subjective scale influencing each person who rates. Especially numbered scales are not used in a linear way, e.g. on a scale from 1 to 6 the gap between 3 and 4 is not perceived as big as the gap between 1 and 2, particularly because 1 is at one end of the scale.[24] They go on suggesting that a rating showing the preference of one item over another offers a better way to classify them.
Our research tremendously influenced the concept and further approach towards the project which is explained in the following section.

3. Concept and Approach

The work involved the research and observation of different approaches to sound visualisation, sound mapping, emotional geography, sensory maps and the project data. The different references build a theoretical basis which was complemented by a workshop with nine participants from backgrounds in architecture, urban

[22] Schubert, Emery (17 Dec 2013): Emotion felt by the listener and expressed by the music: literature review and theoretical perspectives. In: Frontiers of Psychology. DOI: 10.3389/fpsyg.2013.00837.
[23] Evans, Paul & Schubert, Emery (2006): Quantification of Gabrielsson's relationships between felt and expressed emotions in music. In: Baroni, M.; Addessi, A. R.; Caterina, R. & Costa, M. (2006): Proceedings of the 9th International Conference on Music Perception & Cognition (ICMPC9), Bologna/Italy, August 22-26 2006, pp. 446-454.
[24] Martinez, Héctor; Yannakakis, Georgios & Hallam, John (2014): Don't Classify Ratings of Affect; Rank them! URL: http://ilearnrw.eu/sites/default/files/Martinez2014DontClassify.pdf (last accessed: 27 January 2017).

planning, acoustics, music and museology. The project was approached in four main steps, and one or more methods were applied for each.

3.1. Getting to know the *Firenze Sound Map*

We explored Antonella Radicchi's *Firenze Sound Map*, its features and data to better understand the content that would be at the core of its work.
The *Firenze Sound Map* contains 67 data sets of so-called soundscapes. Soundscapes are the part of the acoustic environment as it is perceived and experienced by humans. Acoustic environment refers to the actual, abstract or artificial environments in which sound created by nature or through human activity (sound sources) and modified by the environment exists.[25] In this case, the soundscapes are recordings of different places in Florence.
Each recording is accompanied by a set of extrinsic data: a title of the recording, the name of the person who made the recording, an image, the photographer or image source, the address and geo-referenced location where the recording was made (latitude and longitude), the recording device, date of the recording and time of day of the recording, duration of the recording and a comment.[26]

The observation yielded that the 67 data sets did not hold enough data to handle the project as an extensive visualisation, instead the individual data items were expected to play an important role in the developed concept which would emphasise the quality of the data instead of quantitative aspects. In addition, small gaps between the data sets in Italian and English were discovered (e.g. concerning the translations of the comments) and possible challenges identified. The challenges concerned: the relations between the recordings other than their location, the missing descriptions of the sound recordings and their content themselves or the missing explanations in the comments respectively, and the comprehensive inclusion of all data items in an explorable, visually appealing interface.

[25] ISO 12913-1:2014(en): Acoustics — Soundscape — Part 1: Definition and conceptual framework. International Organization for Standardization, Geneva, Switzerland. URL: https://www.iso.org/obp/ui/#iso:std:iso:12913:-1:ed-1:v1:en (last accessed: 20 February 2017).
[26] Please note that this listing does not mention the new data field "*special thanks to*" which appears in the updated version of the *Firenze Sound Map* from January 2017.

3.2. Development of research questions and research

In order to develop the research questions for the project (see 1.) three topics were studied first: sound visualisation, different types of maps, and the display and playback of sound on websites and in exhibitions.
The initial results were analysed for comparison in each regard. The main findings lead to our research questions as well as first ideas for a visualisation.

As illustrated in section 2 of this paper, it was found that: for most sound visualisations a codification is implemented that is mainly based on the extrinsic data of the sound files – e.g. the frequency, amplitude or volume of the files. These are mostly translated into length, color, position, and in some cases capacity of objects representing the sound. While the presentation is not only limited to 2D visualisations but also refers to 3D objects (see 2.) the limitation in codification remains the same.
Only a few examples pointed towards visualisations that also included motion, such as Savvas Zinonos' *Visualisation of speech*.[27]. Zinonos uses a moving non-static representation that is not digital (other than e.g. the Windows Media Player visualisations), visualising the movements of a speaker cone as it influences the air-pressure and creates "sound waves".

There is a large amount of maps on different matters. Most sound maps were based on Google Maps and contained markers for the position of the sound (were the recording was made) and additional information being revealed in a pop-up element.
R. Murray Schafer's pioneering work in the field of soundscapes was very different from what had been done following his initial documentation and visualisation of soundscapes – he also used words and comparisons, e.g. in his log notes created during a twenty-four hour recording in the countryside on summer solstice[28] or his drawings and descriptions created during the *Five Village Soundscapes* project described above. We were further encouraged by his example of the Lo-Fi-Soundscape to think towards an immersive space that would allow an

[27] Zinonos, Savvas (2012): Visualisation of speech. URL: https://vimeo.com/42164119 (last accessed: 21 February 2017).
[28] Schafer, R. Murray (1974): Soundscapes of Canada. Figure 1: Log Notes from Twenty-four hour recording in the countryside on summer solstice, 1974 Westminster Abbey Manastery, Mission, B.C. (Canada) http://www.sfu.ca/~truax/canada.html (last accessed: 21 February 2017).

in-depth experience of sound and understanding of the somewhat challenging but also defining soundscape of Florence.
As explained earlier noise maps do not relate to the quality of sound.
Lastly, sensory maps, e.g. smell maps, displayed characteristics of color-coding and translations of the immaterial into descriptive words while often not adding to an actual topological, geographic or city map but instead creating it through the words, descriptions or colors.
As afore-mentioned, most digital sound maps explored for this research had very similar features – also with regard to the accessibility of the sounds: There was no autoplay-function and the sound files were usually embedded as bars with a play button on the left and a colored bar representing how much time had passed when playing the sound.
Exhibitions showed a variety of use of sound: on-demand replay of a sound either as an exhibition display or part of an audio-guide, re-play through a trigger (e.g. motion sensors detecting movement), continuous looping[29], random replay[30].

Additionally, we received input from the project partner Antonella Radicchi, who explained the initial motivation for and intention of *Firenze Sound Map*. She specifically highlighted the emotional dimension of the recordings as well as their representation of immaterial heritage. Radicchi's intention was a combination of emotional geography as established by Giuliana Bruno and existing sound mapping approaches – namely R. Murray Schafer – in a "tender soundmap".[31] She aimed "*to go beyond the cognitive approach in (sound)mapping urban spaces*"[32] and explore the relationship between soundscapes and the emotional dimension[33] while creating a space for deep listening[34] and intimacy, which is "*strictly*

[29] e.g. Rosefeldt, Julian (2000): Global Soap. at Künstlerhaus Bethanien, Berlin July - August 2001. URL: http://www.julianrosefeldt.com/film-and-video-works/global-soap-2000-2001/ (last accessed: 22 February 2017).
[30] Jones, Jennie C. (2013): Higher Resonance. at Hirshhorn Museum and Sculpture Garden, Washington D.C., 16 May to 27 October 2013. URL: http://hirshhorn.si.edu/collection/directions-jennie-c-jones/#collection=directions-jennie-c-jones (last accessed: 22 February 2017).
[31] Radicchi, Antonella (2013): Emotional Geography & Soundscape Studies: beyond the cognitive approach in (sound)mapping urban spaces. At: EAEA11 Envisioning Architecture: Design, Evaluation, Communication. URL: https://www.researchgate.net/publication/305929511_Emotional_Geography_Soundscape_Studies_beyond_the_cognitive_approach_in_soundmapping_urban_spaces (last accessed: 20 February 2017), pp. 1-2.
[32] ibid.: p. 1.
[33] ibid.: p. 5.
[34] ibid.

connected to the experience of daily life"[35] and thus should play a role in acoustic planning. Soundscapes can give clues about the identity of a place as they enable the experience of immaterial traits of a city, e.g. social customs, moods or emotions of the human beings.[36] Lastly, through the involvement of citizens, visitors and others, the map has become a collective sound map of Florence.

3.3. Workshop and first sketches

The first input was a basis for the development of a workshop held with nine participants on 19 December 2016. In preparation of the workshop, we selected 20 sounds from the collection. For the purpose of the workshop we provided the 20 sounds, an image of their sound graph, the accompanying image and information (date of the recording, geo-location, recording device, person who recorded the sound etc.) of the data sets, further images of maps and the city of Florence, different pens, felt tips, pencils, glue and scissors, and DIN A2 paper.[37] Two exercises were conducted during the workshop. In the first exercise the whole group was divided into two. Everybody listened to the same sound and was asked to draw while listening to the sound. While one half of the group closed their eyes, the other had their eyes open. Two main formats became visible, while the first group had concentrated on representing highlights of the sound through different symbols or differently directed lines, the other half had mostly drawn a scenery as presented by an on-looker. One participant drew a kind of immersive soundscape-like image with a person in the center and sound represented through spherical doodles surrounding her.

In the second exercise the group was asked to create collages of the material listed above. Afterwards these were hung up and everybody had a bit of time to look at the collages which were subsequently analysed and discussed in the group.

The main findings of the workshop were:

- a map for orientation is an appreciated feature
- at the same time focussing on the sound should be encouraged in order to experience it

[35] ibid.: p.3.
[36] ibid.: p. 5.
[37] Minutes of the workshop in Annex 1

- perception & personal experience influence the relation to the content
- users might want to contribute their own opinion, perception or even stories
- playing with different kind of media is appealing
- one of the collages was a "sonic postcard of Florence"
- the sound of bells was perceived as very representative for the city of Florence and referred to several times by the participants

Based on these findings, the previous research and talks with Antonella Radicchi, Prof. Marian Dörk and the seminar group of the course Visualizing Cultural Collections (winter semester 2016/17) the first prototype was developed.

3.4. Developing the first prototype

For the development of the first sketch we decided to use a collaborative process. Based on the literature review and conclusions drawn from the workshop each one of us prepared sketches, which we then presented and explained to each other. With this clustering of ideas through the method of external thinking, we were able to discuss and agree on ideas and approaches we considered to be relevant and recognised as feasible within the time frame. This version was characterised by different modes to explore the sounds and enable the viewer to decide how much content should be displayed. It failed to connect the different approaches/modes to experience sound with each other and was rather static. Users could rate the sounds, but it was not clear what the categories would be and how they could be related. Overall, the sketch did not hold enough space for an in-depth exploration or immersive experience responding to the emotional dimension of the *Firenze Sound Map* and its soundscapes.

Through a series of adjustments we came to develop a more immersive 3D environment and decided to introduce the "acoustic flaneur".
We chose to introduce four different modes as is explained in the following section. In preparation of the interface proposal, we listened to the sounds and developed tag words based on the sounds as well as the accompanying comments, since the database did not contain such tags. The comments that had previously only been available in Italian were translated by Antonella Radicchi.

From the previous research regarding ranking, it became clear that a difference between the kind of emotions and those who captured and those who perceived them had to be made. Furthermore, it became clear that the rating might not be the preferred method as the comparative process of ranking seemed much more helpful.
While the focus was not on music but soundscapes, the emotions had to be distinguished differently to take into account new factors. Instead of having felt and expressed emotions, there were a number of influences: the intention of the person who recorded the soundscape, the feeling of the person recording the soundscape, the perception of the recording by a listener, the possible influence of a comment on the perception of the listener.
The comments in the data were very diverse, also to the extent to which they expressed the feelings of the person who recorded the sounds. Not all comments gave away that information, thus using emotive tag words by referring to the comments was dismissed early on.

An in-depth description of the design is available in the following section.

4. Design and Implementation

After a research and workshop phase, the team started a design phase aiming at developing a prototype that promotes the exploration of a soundscape in a more emotional way. For this stage, we used Cinema4D to create a 3D environment. Overall, we proposed an interface that is built around an arrangement of balloons scattered through a virtual 3D space, each balloon representing one of the 67 soundscapes from the *Firenze Sound Map* collection. The balloons are positioned according to their geographical data, i.e. the latitude and longitude of the places where the recordings were made (x- and z-axis). A simplified map is shown at the base of the interface, which offers a bird's view. It is possible to toggle the map on and off. Due to the original purpose of the field recordings, which is to describe a space through the use of sound, we decided to keep this geographic data as an "anchor" for the balloons. Hence, the balloons float over their location on the map. Furthermore, one can say that a field recording is an immaterial description of an actual existing place. To illustrate this immaterial characteristic, we picked balloons as graphical elements to transport the ethereal and fleeting nature of the

collection. In our prototype, the viewer can click on each balloon to listen to the according sound recording. After the sound recording was played, the balloon flies away and disappears, which stresses out the ephemeral nature of sound. A reset button allows to go back to the initial state.

The 67 items of the collection have been recorded over many years by various field recorders, i.e. people exploring the city by actively and intentionally concentrating on the sound environment during so-called "sound walks", much like what W. Benjamin's describes as the activity of the "flaneur".[38] We wanted to translate this exploration activity into the interface by allowing the viewers to move from balloon to balloon in the 3D space much like in a 3D-modeling program (pan, rotate and zoom). We hope that this will foster serendipitous exploration by listening to one sound and moving to the next one. The user of the interface could thus become an "acoustic flaneur", similar to the information flaneur described by Marian Dörk[39] , but using primarily the sense of hearing.

We decided to divide our interface into four modes that support different activities: listening, exploring, rating and uploading sounds. These modes are accessible through a menu at the top.
The first mode focuses on **listening**. In this mode, the level of visual information is kept intentionally low so that the user is not distracted from the hearing activity.
The second mode is focusing on **exploration** based on the metadata. In this mode, the viewer can still navigate through the 3D space, but additional information is shown by using differents means. A postcard is attached to each balloon. The viewer can enlarge the postcard by clicking on it. This shows the photograph that was taken at the spot of the field recording. Another mouse click on the postcard makes it turn, displaying the author's name, title, location and time of recording, as well as the author's commentary. This allowed us to keep the overall view simple. We also think it could engage the viewer in a serendipitous exploration activity because some information is hidden and needs to be discovered by actively navigating through the balloons, which could raise the viewer's curiosity.

[38] Benjamin, Walter (1983): Paris, die Hauptstadt des XIX. Jahrhunderts In: Tiedemann, Rolf (editor): Das Passagen-Werk, vol. 1, Frankfurt am Main 1983, pp. 45-59.
[39] Dörk, Marian; Carpendale, Sheelagh & Williamson, Carey (2011): The Information Flaneur: A Fresh Look at Information Seeking. In: CHI 2011: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, May 2011, pp. 1215-1224.

Another important part of the exploration mode is the tag cloud. During our research phase, we listened to the sound recordings and tagged them according to their content. We decided to present the tags above the balloons, in the "sky", as a tag cloud. Each tag can be selected and acts as a filter. When a tag is selected, the balloons that have been tagged with that word are highlighted. This can show relations and patterns between various balloons, even though they are geographically separated.

The third mode is used for **rating** the sounds. Describing a sound with words is arguably one of the most difficult tasks, when it comes to sound research, since everybody feels differently about one particular sound. There are also different ways of describing a sound, for example, you could use verbs to describe actions (what is happening, e.g. humming), or you could use a noun of what you think you hear (e.g. a car), or use an adjective to describe the quality of the sound (e.g. loud, or calming). Our first solution allowed the viewer to rate each sound according to three different parameters, displayed in pairs (good/bad, eventful/uneventful, pleasant/unpleasant). However, this solution appeared to be limited and constraining. Therefore, we chose to offer more pairings and also the possibility for the user to provide additional pairings, if the ones at his/her disposal appear to be insufficient. The user also has the possibility to add tags to the cloud, for each recording.

As for the rating, we decided not to use a linear scale because of metric regression. [40] Since the parameters are subjective ratings and everybody's perception is different, a classification (the nominal translation of numbers into categories - e.g. high, low, neutral) is also difficult.

We therefore decided to use the height of the balloons without a scale , to leave it a a bit more open and in order not to mislead the viewer with visual clues that evoke rational objectivity.

The fourth mode is dedicated to the **uploading** of the field recordings. Although we have not designed this part yet, it could contain an online form offering easy contribution, as well as some automatic checks which would ensure that the data provided is consistent.

[40] Metric regression refers to the fact that rating always has underlying numeric scale and is non-linear - i.e. with a scale from 1 to 6, the gap between 4 and 5 might be smaller than between 5 and 6.

This interface is still in a conceptual and graphical phase. After a feedback round, it would be useful to create a first functioning prototype, allowing to test if our assumptions regarding the improved explorability are confirmed. The next part will show some of the feedback we received and decisions we made.

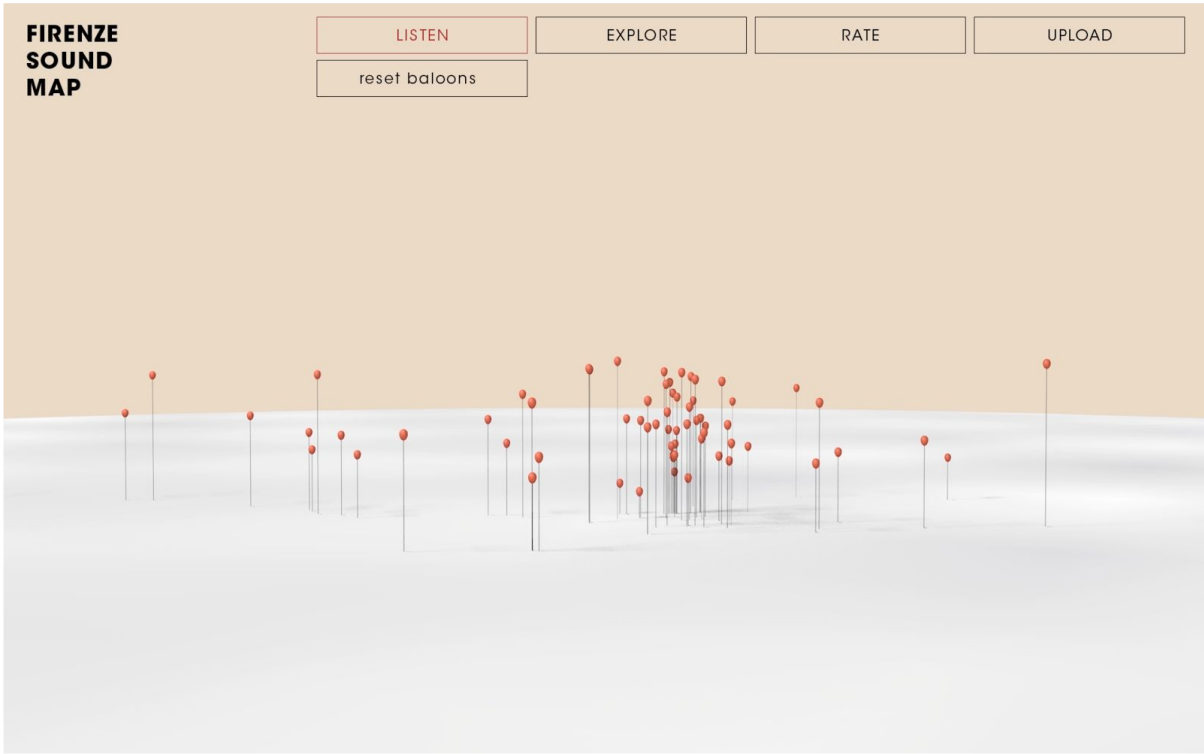

Fig. 3: The Listen mode of our prototype

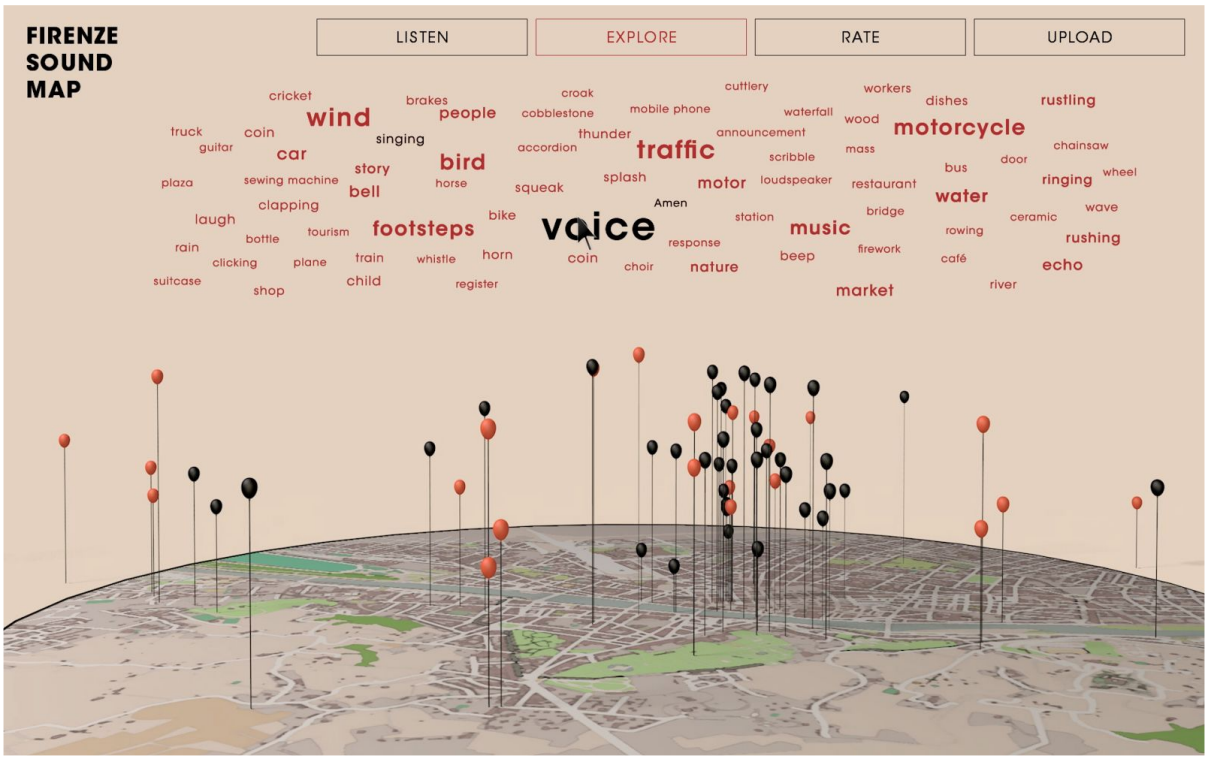

Fig. 4: The Explore mode of our prototype, showing the tag cloud

5. Evaluation

The interface prototype was presented on 3 February 2017 to an audience of about 30 people active in the field of information visualisation, information sciences, cultural studies and design during a 15 minute presentation and at a small demonstration table. Overall the ideas were well received. Especially the approach towards an immersive environment allowing the visitor to focus on the sound was well-received by the audience.
We shared the prototype with Antonella Radicchi on 9 February 2017, who concurred with the overall design and ideas aiming at improving the integration of the recordings and the overall experience, and gave us valuable feedback

In the following the critique points on the interface proposal will be discussed, especially concerning the overall appearance and function of the visualisation, then we will suggest possible solutions or starting points for further research for the different modes.

One of the main critique points was the static presentation of the balloons. The straight line connecting the balloon to the ground should be more jumbled. Furthermore, it was suggested to have swaying balloons, indicating a kind of breeze. Additionally, balloons could fly away not only after playing, but throughout and users could have a chance to catch them.
We agree with the critique of the static appearance and plan on adjusting the presentation. The idea of sounds not being played also flying away from time to time makes a lot of sense especially with regard to their immaterial quality, we would have to think of ways to make these sounds also audible when they are about to disappear or implement a suitable mechanism to enable users to catch them. Once coding comes into play an approach towards random selection of sounds flying away dependant on the display section visible to the user has to be developed.
Another suggestion was to have the balloons fly away after filtering in the explore mode. This was dismissed because the selection is already made visible through colors, also balloons might have to re-appear once a filter is changed.
The audience shared different ideas in terms of the balloon size and color. We decided that the color of the balloons indicating any kind of content was a difficult

approach. Given the small surface available, it did not make sense to represent neither the different tag words nor the possible mood of the recording by using colors. Color is a visually strong element and should be used to distinguish and highlight a very specific feature. In our intended approach this would have to be the mood or emotion of the person recording the sound or the users. The former, however, cannot be reconstructed. Additionally, defining labels for emotions and suggesting suitable categories would require further research. Besides, a color code would first have to be learned by the viewer. It could also be misleading to some of the users if the chosen colors appear to be counter-intuitive.
Regarding the size, particularly the volume of the balloons, we found the data to be too diverse to assign volume as a representative value to any of the entities. For example, the duration of the recordings ranged from 9 seconds to 3 minutes and 11 seconds. Creating a distinguishable scale for the volume of the balloon with regard to the recording's duration is nearly impossible. Another problem is the proximity of the recordings, some were made in the same place, so in order to not disregard physics the balloons could not be next to each other. Applying volume with regard to the range is, as explained in section 2 not possible with the existing data and the method applied to retrieve it. Documenting such information would also lead to a barrier for user contributions which opposes the intention of a collective sound map.
As for the rating, it occurred to us that our solution does not take into account how many ratings have been given for each sound. This valuable information could be added in a future version of the prototype.

An important question was how the viewer would be invited to click on and listen to one of the balloons or sounds respectively. Here we decided to use the floating and swaying balloons, as they would suggest movement and particularly a "clickable" area.
In addition, a small help button, e.g. a question mark, should support users to orient themselves. Another option would be to have a voice-over early on inviting clicks and implicitly drawing the attention to listening.
This remains one of the main challenges. Providing focus on listening rather than having visual distractions cloud the experience is one of the most demanding issues we have been dealing with from the beginning. In the next steps we should be experimenting with colors, possible fading screens, growing balloons, zooming

into them or other methods to explore the possibilities. We would suggest to do this as a user study with different subjects. A persona approach seems to be not as suitable for this particular question now as it is difficult to imagine preferences and test usability for this regard with "made-up" representations of different audiences.

Placed in a rather inconspicuous spot, the invitation to upload personal recordings should be highlighted more. A clear encouragement and defined format for submission, e.g. a defined form or a specific app, should make this possible. Additionally, a good administrative scheme for quick implementation would help generate usable and comparable data sets.
For this, an audience member pointed us to George Legrady's *Pockets full of Memories* where user-generated content – pictures of objects along with a comment – is welcome and the resulting database displayed in such a way that semantic relations are translated into spatial proximity of the images on a screen.[41]

We had decided for the location-based display of the balloons, but could see this option to be included in the Listen Mode or adopted for the Rate Mode.

In the following the further comments, suggestions and possible further research and evaluation will be presented for the different modes.

Especially the listen mode, as it is the start screen, could invite the user in the beginning to concentrate on listening by establishing it as a relevant aspect of the display early on. This could be achieved through a voice introducing the use of the sound map or the options mentioned above.
Other afore-mentioned aspects such as the possibility to grab balloons flying away or using the brightness of the screen or dark filters to accelerate the focus on listening were particularly discussed for this mode.

To make the connections between the modes more visible the Explore Mode should indicate the sounds the user already listened to in other modes or this one. This is challenging, as three colors are already used to display the regular balloon color, the sounds selected through the tag words and the balloon one is currently

[41] Legrady, George (2001): Pockets full of Memories. URL: http://www.medienkunstnetz.de/works/pockets-full-of-memory/ (last accessed: 22 February 2017).

listening to. An option could be transparent balloons reflecting the “fading” sounds.
An automatic zoom showing selected balloons close-up will help make the postcards visible. This is necessary in order to not disregard them.
Also it needs to become clear that the postcard has a backside and can be flipped. A simple icon on the postcard or the use of the breeze flicking part of the postcard could encourage users to flip the cards themselves.
Further information from the database could be included on the postcards, e.g. the date of the recording as the date when the card was sent out. The idea of sender and receiver needs to be adjusted, at the moment the location and the person who made the recording are listed as the recipients of the card. But this would either be the Firenze Sound Map or the visitor to the website, while the person who made the recording is the sender. The space for an address also offers a good opportunity to offer a field for email addresses or similar options to enable users to share “sonic postcards“ from Florence.
The tag cloud was generally welcome by the audience. Slight adjustments of the scope were suggested, e.g. the person who recorded the sound so users can listen to the sounds recorded by the same person. An additional connection could be through the ratings. At the moment the rating (or rather ranking) cannot be explored so well, because in the rate mode the user is immediately invited to take action him- or herself. This could be a place to connect the two modes.
Another option could be to introduce a second tag cloud taking into account the emotions and rankings of the sounds. This greatly depends on the categories selected for the rate mode. The exploration of the rate mode could also be included through different viewing options in the latter, but this would interfere with the current division between explore and rate mode. Here a color-code for the different emotions or rating categories could be discussed but has to be considered in regard to the existing color scheme.

We agree with those who pointed out that the rating categories and terms need to be separated or defined more clearly. This is also in order to deepen the exploration of the emotional relationship between the sounds and the user.
One option would be to not indicate a scale or ranking between two words but change the question behind the approach from “What is it more like“ to “What is

and isn't it?" through either tag words, e.g. irritating, calm, quiet, noisy, or yes/no-questions "Do you like this sound?" or "Is this loud?".
It makes sense to also invite users to contribute their own tag words, particularly for this mode, or add comments to particular sounds to explain their ranking. A possible question could be: "How does this sound make you feel", which is comparable to the United States Holocaust Memorial Museum's approach in their online exhibition *Some were neighbors* allowing users to provide their own tags by asking *"In one word – what do you see in this picture?"*[42] or to reflect on certain images and contribute a comment in the designated section called "*Reflect*" on the website.[43]
One difficult issue for the rating is the 3D perspective. Different heights of balloons will not become as clear as they could. Thus a coloring option or a clear distinction between two options rather than a proximate positioning or a rating with different bars and sliders than the balloons themselves are options that need to be investigated further.
Several open questions and opportunities remain for the prototype to be developed into a full immersive experience that puts a particular emphasis on emotion and listening (through visual indicators).

6. Future work

This prototype has shown that exploring a city's soundscape though a reduced visualisation focussing mainly on sound represents an untapped potential. The content of the listed soundscapes is described by tags and the emotions are displayed by different tag categories too.
There is of course still room for more improvements and further thinking on optimizing the use of the data. The existing metadata of the database can be used as additional entry points to the sound map, allowing access to the information in a more engaging way that entices the viewer into the cities soundscape.
Furthermore, additional data from the city (e.g. tourist movements, public transportation use, noise pollution levels, ...) could also be included to show new relations, contrasts or contexts. Connecting different types of maps with sound maps would allow broader insights, the combination of sound maps with noise maps results in showing relations between the noise pollution level and the

[42] United States Holocaust Memorial Museum (2013): Some Were Neighbors. URL: http://somewereneighbors.ushmm.org (last acceessed: 12 February 2017).
[43] ibid.

contained sounds and even the experienced emotions. Louder sounds do not automatically stand for a more unpleasant feeling. A mobile app optimization for our interface is also conceivable: location-based tracking would enable the soundscapes that are near you. A smartphone app could also make the participation process more appealing by offering an easy recording and upload functionality. Sound maps would become more interesting with bigger databases, making it possible to compare city zones, areas, and even cities. This project could also address different areas of research and may possibly offer a helpful working tool among others to urban planners, sound researchers, cultural scientists, interface designers.

7. Conclusion

Overall, it was our goal to create more of a qualitative visualisation than a quantitative one. On the one hand this was due to the limited number of 67 data sets, on the other it was based on the original intention of the *Firenze Sound Map*. The sounds are meant to represent the city as a social habitat and depict its characteristics, culture and identity. With our approach we intended to entice viewers to an in-depth exploration of the city of Florence through the eyes and ears of a visitor or citizen of Florence. This approach takes into consideration individual contributions to the overall “soundscape” of the entire city, which is made up of many small soundscapes. As such, sound maps could play a bigger role in society by becoming participatory data collection tools that foster civic engagement to protect each city’s immaterial heritage.

8. Annex

8.1. Annex 1 - Minutes from Workshop 19 December 2016

Participants: Tommy Wirth, Cristina Toderova, Pia Weishaupt, Marie Lührs, Antonella Radicchi, Dietrich Henckel, Thomas Kusitzky (left early), Max Harbel, Anna-Lena Vogt

Facilitators: Stéphane Flesch, Anne-Sophie Gutsche

15:06 beginning

- Introduction of Stéphane and Anne
- S. introduced the topic and InfoVis course briefly
- Antonella was invited to briefly explain her "Firenze Sound Map" project

First task

- Listen to sound no. 51 and draw
- Group A with eyes closed
- Group B with eyes open
- Hung up images and compared:
    - Group A drew more abstract images, beeps were highlighted through marks, rhythm was identified
    - 1 person found this task easier/natural as this is how she listens to music
    - Group B mostly imagined a scenery and drew it, the results were rather similar in three cases, in one it was different
    - While 3 participants were like onlookers, they drew a scene of a market with one or more cashiers, one person drew a soundscape with a person in the middle surrounded by different noises (emerged in the space)

Second task (started at around 15:52)

- Work with the 20 pre-selected sounds, the accompanying metadata, soundwaves, pictures, as well as other material (scissors, gluesticks, yarn, coloured paper, pencils, pens, other pictures, maps, soundwave depictions…)
- Thomas Kusintzky had to leave early at around 16:07

- 3 participants started by listening to the sounds first, one of them listened to all the sounds, one started and began from the first sound she liked, one listened to selected tracks (at random)
- One participant started from the soundwaves, it was a coincidence that they all contained bell sounds/ecclesiastical noises
- One participant started from the pictures of the data
- One participant started from her own experience in the city of Florence and the pictures
- One participant discovered the sound of a train station (through the picture?) and as he was drawn to it because he likes the soundscapes of train stations and airports, he choose to start his work from there
- The other two participants did not specify their approach

- The participants asked for more time when the 30 minute mark was approaching, in total the working period was extended to 45 minutes

- Following the working session, the created images/collages were hung up (Thomas Kusitzky's collage was hung up at this point too, not to distract the participants from their approaches)
- Afterwards, participants and facilitators were given 5 minutes to look at the creations to then continue with a discussion

- The first question was: Which collage appealed to you most or which one raised questions for you?

- Anna-Lena and Dietrich both pointed out Cristina's collage (little girl on swing twice - https://goo.gl/photos/YxkANY3T39sWKZjb8) as "interesting combination"
    - she used one comment only (an Italian poem, which was played like a piece of music – Antonella added), two soundwaves, images from the data but also other images
    - Stéphane found it too be more visual, state of mind, more so visual than information transfer; Pia: safe/protected room, with play and fun; others disagreed with this perception, especially because of the opening area/arcades of monastery; Cristina about her own image:

child on swing like a clapper of a bell, opening up into sound, soundwave standing upright like one of the columns (?), extending beyond the one scape – all connected and interwoven

- The bell sound was reflected by several participants:
    - Marie went from the noisy places (in part due to the bells) to a quiet place as remembered from a previous visit to Florence (from the Christian loud noises to the Jewish Synagogue), her image was a bit 3D, because she wanted the people not to be connected to the buildings (which impressed her during her visit) and cut them out, more a labyrinth (all dead ends except for the one that leads to the quiet place)
    - Pia created a path from the peaceful bell sounds to the noisy place/market/many people, here she added a few images of people to represent the level of the sound more clearly (she approached the task by starting from the images and then listening to the accompanying sounds, creating path of a tourist, the path is divided towards the end, and it doesn't have to end there, it's only what Pia did
    - Dietrich who had looked at the soundwaves first had selected mostly bell sounds and thus titled his collage "bells and voices"
- It was commented that the bell sound was audible in almost all of the recordings

- Max selected the train station as a starting point, he perceived it as a pleasant sound, because he enjoys the soundscape of busy places such as airports and train stations, however his visualisation was perceived by many as negative, mainly evoked by the black frame around it, which he used to symbolise bouncing of the walls/echoing of the sound (also represented through the divided soundwaves)
- Pia used the terms "silence/peace" and "stress/dirt" while Tommy used "quiet" and "loud" to represent the sound in his image "noise pollution map" – their approach and perception was very different in terms of the emotional level, Tommy located the sounds on a map and marked them as loud to create kind of a noise (heat map) – he did not know such thing already existed
- Anna-Lena commented about her collage that the images she had in mind when listening to the sounds did not match the images provided by the ones

who recorded the sounds/added in the data, thus she wanted to create collages of different and new images for this, as well as locate them on the map (only did so for one sound)

- Antonella created a kind of sonic postcard from Florence, using one image (not from the data), one comment, one set of coordinates and the names of many sound recorders, she had trouble making her ideas come to life, as she had listened to all the sounds and then started working with them and time was rather limited
- All were very interested to find out more about Thomas collage, it was suggested that it could represent several smaller soundscapes, with different characteristics (marked through different coloured dots)

- Everybody enjoyed the workshop and found it to be interesting, fun and in some cases inspiring
- A follow-up of the workshop is of interest to the participants, including images and some key aspects to be highlighted
- Everybody was invited to attend the presentation on 3 February 2016

18:00 end of session

- Things for the group to take with them:
    - word and tag clouds could be interesting
    - difference between what you expect and what you see
    - labyrinth, story, path – storytelling approach vs. map orientation
    - bell sounds as connecting characteristic
    - exploring and navigating through hearing only?
    - Game approach?

Fig. 5: Examples of some collages produced during the workshop

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10. Table of Figures