Sensing the Crowd: Enhancing the DJ's Perception in Nightclubs

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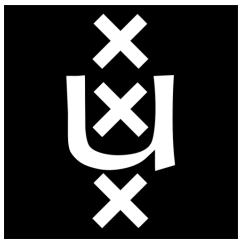

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ABSTRACT
This paper presents the requirements, design and evaluation of a visualization to support DJs in sensing the crowd's energy level. We identified the requirements DJs hold towards such a visualization by triangulating a survey completed by 30 DJs, five transcribed weekly published DJ-podcasts and a direct observation of a DJ performing live in a nightclub. The visualization is based on wearable sensor data about the location and movement of the audience during a nightclub event. The visualization was evaluated by six DJs in a think-aloud user test and a semi-structured interview. The evaluation leads to the validation of our hypotheses: DJs were able to understand the crowd better through the proposed visualization. The DJs provided us with additional needed features the visualization was lacking. The visualization should undergo further user testing in a more realistic setting and further research concerning the implementation is advisable.

Author Keywords
Data Visualization; DJs; Sensing; Crowd; Performance; Nightclub; Activity; Wearable; Sensors.

ACM Classification Keywords
H.5.1 **[Multimedia Information System]**: Evaluation/methodology; H.5.2 **[User Interfaces]**: Prototyping.

1. INTRODUCTION
Nightclubs invite people into a space that fosters interactivity [11]. People go out to meet others and share experiences. It seems strange that these spaces dedicated to interaction between audience members leave little to no room for interaction between the audience and the performer [7]. The interaction with the crowd plays a key role for the DJs. It enables them to receive feedback from the crowd and to adapt their performance accordingly [7]. DJs have to recognize the energy level and reaction to their performance by the audience only based on their own sensitivity. This can be challenging for inexperienced DJs and adds a layer of complexity to the already complex working conditions in a nightclub; the pressure of performing live, processing of visual and auditory influences and multitasking during performances [1,7].

In this thesis, we developed a visualization that shows the energy level of the crowd in a nightclub. The data for the visualization comes from wearable sensors integrated in wristbands worn by the audience in a nightclub. The sensors collected various information, inter alia, the location and movement of each individual. The aim of the visualization is to support DJs in understanding the audience's reaction to their performance, and thereby increase their insights and potentially improve their future performances.

Our hypothesis is that a visualization of the audience's energy level helps DJs understand the crowd during live performances. In this thesis, we test this hypothesis by answering the following research questions:

- Are DJs interested in a visualization of the audience's energy levels?
- What requirements do DJs hold towards such a visualization?
- Can a visualization support DJs in sensing the energy level of the crowd, considering increase of insights, effectiveness and acceptance?

This study follows a mixed approach based on the design science research methodology introduced by Peffers et al. [17]. We first define requirements, then we develop a prototype and finally evaluate it through user tests.

The remainder of the thesis is structured as follows:
Section 2 reviews previously published literature in the field focusing on the DJ's perspective concerning audience feedback and the DJ-crowd interaction. Section 3 outlines the methodology approach of this study. Section 3.1 specifies the triangulation used to identify the requirements and describes the individual process, 3.2 focuses on defining the requirements DJs hold towards a visualization. Section 4 describes the developed visualization, section 5 illustrates the evaluation method, its details and its outcome. Finally, section 6 presents the discussion and future research and section 7 contains the conclusion of this study.

2. RELATED WORK

2.1 DJ's perspective

In order to assist DJs with their work, it is necessary to understand what their main goal is: The DJ wants to keep people dancing. Their aim is to pull the audience onto the dance floor and engage them as long as possible [1, 19]. To archive this goal, DJs go through three steps during their preparation and performance: collection of music, performance and self-promotion [1]. Multiple studies carried out by Kaiser et al. [11], Laursen et al. [14] and Barkhuus and Jørgensen [2] suggest focusing on these specific overarching phases for the development of tools to support DJs within the defined tasks. For our study we focus on the performance phase.

2.2 Audience feedback

Focusing on the DJs performance, Laursen et al. [14] state that DJs, to fulfill their goal, have to satisfy the members of their audience – the crowd [7]. To achieve this, they need to pay close attention to the crowd's feedback [7, 22]. According to Karnik et al. [12] most DJs find it especially helpful to receive feedback on social network systems. Online audio distribution platforms such as SoundCloud[1] offer users the opportunity to comment on specific parts of a set, enabling DJs to receive feedback on their work. However, the reception of feedback offline is a complex area, as an audience member does not have the ability to leave a comment on certain parts of a set. Therefore, previous studies in the HCI field focused on developing interactive technologies to improve the communciatiob between the DJ and the crowd in nightclubs [7]. When measuring audience engagement using sensors during a theater performance, Latulipe et al. [13] suggest that these measurements can lead to an evaluation tool which grants insights into how the audience receives a performance.

2.3 Interaction with the audience

The social interaction with the crowd plays a significant role to performers [22]. Barkhuus and Jørgensen [2] explore closely the interaction between audience and performers to develop a 'cheering meter' for live rap-battles. They found that reactions during performances often follow a predictable pattern. Audience members are aware that they can provide positive feedback by, for instance, clapping at the end of a song or during specific points of the performance, such as solos or when recognizing the first lines of a well-known song the artist is about to play. However, these patterns are a lot more difficult to detect and react to in a nightclub setting. During live performances, DJs use visual and auditory cues to make up for these features [7, 14, 19]. For example, they are able to gain an understanding of how their audience feels about the performance by listening for cheering, clapping and whistling, which are common ways of complimenting and congratulating the DJ in the nightclub scene. Experienced DJs develop a certain sense for the needs of their audience, adjusting and planning their sets according to the mental and physical shape the crowd is in and taking the time period of their performance into consideration [1].

Previous studies found that DJs face multiple challenges in sensing their audience in order to adapt their performances accordingly. Gates et al. [7] conducted a study concerning the way DJs interact with their audience in nightclubs. They established that the crowd-DJ-interaction is very complex due to various challenges DJs face during their performance. Dance floors are usually not well lit, the DJ booths are someftimes located in a way which makes it close to impossible for the DJs and audience to see each other and the auditory load is high. All these factors add to the cognitive load DJs experience while under the pressure of performing live [1, 7].

3. VISUALIZATION REQUIREMENTS

With the aim of creating a visualization to help DJs overcome these challenges, initial data was collected and analyzed to identify and understand the requirements of DJs. We used these insights to create the visualization. As suggested by Gates et al. [7] and Webb et al. [22], we focused on the role of the DJs and how they perceive the interaction with their crowd. We collected the data from three sources:

1. An online **survey** which we shared on social media platforms and via e-mail.
2. Transcripts of five interviews of the weekly published **podcast** series 'Resident Advisor Exchange'[2]
3. A **direct observation** of a DJ in a nightclub.

The triangulation of these methods was used to confirm previously recognized concepts and to identify new concepts, needs and desires of the DJs [4, 6, 10, 23].

3.1 Methodology

Details about the methodology to gather the requirements are described in this section.

Survey

With the goal of reaching a broad audience, we used an online survey (see Appendix A) to gain insights into the current state of the DJ-crowd-interaction and identify demands to a visualization [8, 10, 15].

[1] https://soundcloud.com/

[2] https://www.residentadvisor.net/podcast.aspx

The survey was shared on Facebook, LinkedIn and djforum.com to reach a variety of respondents from different cultures and backgrounds. In addition, it was sent to specific DJs and promoters, who we asked to disseminate the survey in their network. As an incentive, participants could win two one-year pro accounts for the online audio distribution platform SoundCloud. Survey respondents answered open-response and multiple-choice Likert-type scale questions about their individual music style, habits, interaction and experience with the crowd.

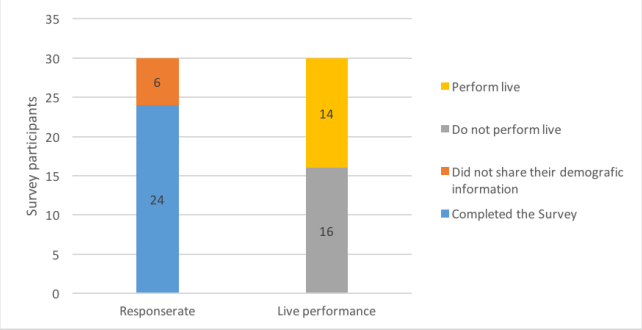

Figure 1. Divisions between the 30 survey participants

We surveyed 30 DJs: All of them finished the survey, but six of them did not share their demographic information. Nevertheless, we analyzed all 30 responses because all relevant questions were answered. Out of the 30 DJs, 14 perform live and 16 stated that they do not perform live (see Figure 1 for clarification). Questions about performing live were only addressed to DJs that previously answered that they do perform live. Due to some open answer responses, we suspect that some of the DJs answered this question inaccurately, because they referred to live performances in some of their responses even after stating that they do not perform live. The demographics of the respondents are: 14 live in Germany, four in the Netherlands, two in the United States of America, one in Spain, one in Austria, one in Canada and one in Tuvalu; six did not share their location information.

To identify correlations and differences in the Likert-type scale responses given by the DJs, we used the Wilcoxon Signed-Rank Test and Spearman's Rank Correlation Test. The open answers were analyzed using inductive content analysis [9, 21]. First all open-response questions were read to achieve a general overview of the data. Afterwards the answers were studied more carefully, sections concerning the reading of the crowd were highlighted and keywords were written in the margins. Afterwards, the most frequently used keywords were grouped into themes and coded throughout the data detailed in the result section.

Podcasts

DJ podcasts were used to gain insights into the knowledge of experienced and well-known DJs with the aim to uncover more precise needs and desires consistent with the approach by Dandavate et al. [6]. The possibility of using podcasts was discovered by reading through forum posts (djforums.com, djtechtools.com) where DJs recommended to listen to podcasts to seek more information on how to improve.

Resident Advisor[3] is an online electronic music magazine with 97,700 followers on SoundCloud[4] and 561,778 followers on Facebook[5]. The magazine releases a weekly podcast series called the 'Resident Advisor Exchange'. The series features conversations with artists, label executives and promoters shaping the electronic music landscape.

We analyzed five podcasts dating back to May 8th, 2017 [25, 26, 27, 28, 29]. The data was collected by listening to each podcast while writing down timestamps for the parts of the interview which concerned the interaction of DJs with their audience. Afterwards, these sequences were transcribed. The raw textual data was then analyzed in the same manner as the open-response survey question above: using inductive content analysis to find themes and highlight important sections [21].

Direct observation

A direct observation was undertaken to understand the context in which the visualization could be integrated [20]. By placing the researcher directly into a nightclub setting, environmental and usability requirements were identified [18].

The field study took place in the 180m^2 club VLLA[6] in Amsterdam. During a two-hour live performance on April 16th, 2017 we observed one DJ in their work environment. To conduct a focused observation, as suggested by Wong and Blandford [23], we decided to target the interaction between the DJ and the crowd, the general tasks of a DJ right before, during and after a performance, and the surroundings and challenges DJs face during their performance.

The data was collected by composing notes and photos of the targeted behavior on sight. Subsequently, the notes were rewritten and turned into more specific records. The records included the description of the physical context (see Figure 2), the crowd, the tasks and the interaction between the DJ and the crowd. Through this technique we were able to

[3] https://www.residentadvisor.net
[4] retrieved on June 5th 2017
[5] retrieved on June 5th 2017
[6] http://www.vlla.nl/

define requirements by identifying important information and insights throughout the data.

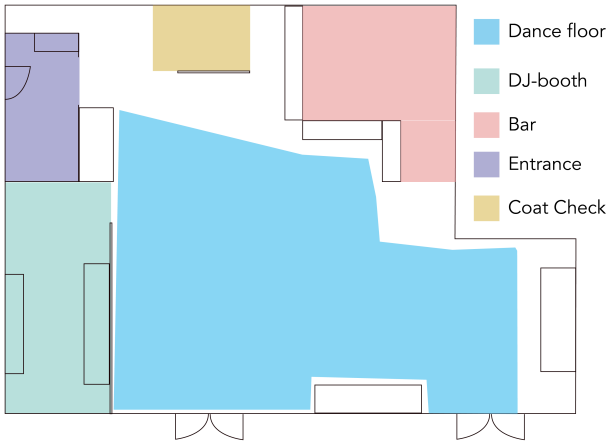

Figure 2. Recreated floor plan from the observed club

3.2 Requirements for the visualization

Insights gained from the collected data showed that DJs view sensing the crowd as one of their most important tasks. Our findings show that DJs see sensing the crowd as a skill which is developed over time and with the experience of multiple different performances. They experiment with tracks to see how the crowd reacts to specific moments during their performance. In addition, we identified what kind of information DJs gather during a performance. We also discovered visual, auditory and other challenges DJs face. Additionally, we observed different zones on the dance floor visible and invisible to the DJ. Our findings are detailed below and concluded in a summary of the major findings and requirements gathered for a visualization.

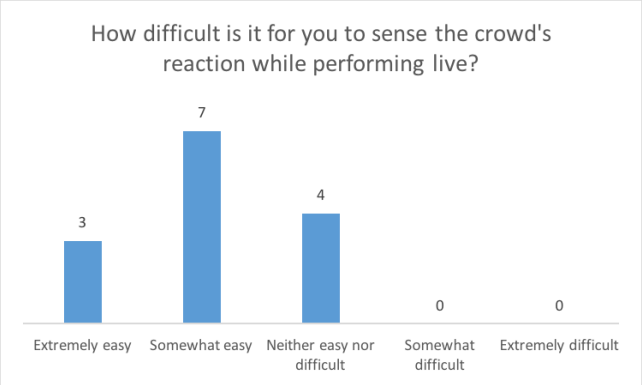

Figure 3. Answers given to Question 13 by the participants in the online survey

Sensing the crowd is relevant to DJs

In our online survey, 13 out of 14 live performing DJs answered that understanding how the crowd feels during their performance is important to them. While none of the DJs ranked sensing the crowd as particularly difficult, only three DJs reported no problem at all with sensing how the crowd feels about their performance. Figure 3 shows the distinction between these responses. Additionally, the inductive content analysis of the open-response questions identified 'how the crowd feels' as the most mentioned theme after further developing their craft (see Figure 4). We can therefore say that sensing the crowd is highly relevant to DJs. Our findings match the ones by Gates et al. [7] who stated that understanding the audience plays a major role to performers.

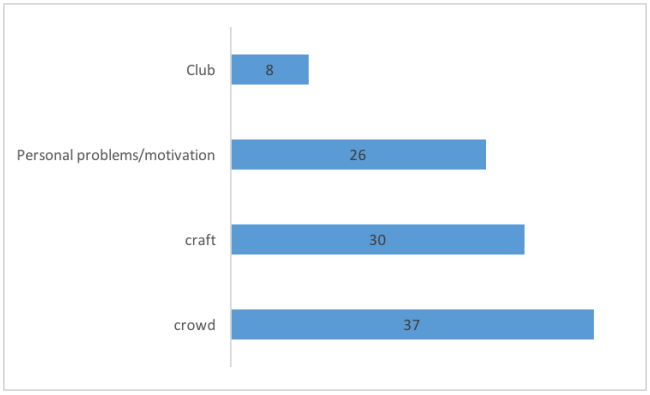

Figure 4. Identified themes in open-response questions

Skills developed over time

We found a correlation between DJs with more experience in live performances and how they feel about reading the crowd. We correlated answers – using Spearman's Rank Correlation - given to two questions by DJs with their level of experience. The first question was how much they adapt their performance according to the crowd's reactions and the second question concerned the difficulty of sensing the crowd's reaction.

Based on the results of the study, DJs with more experience tend to adapt their performance slightly more often to the crowd's reaction rho = 0.572 (moderately correlated), p-value = 0.0326. The survey indicated that DJs with more experience feel slightly more confident about receiving feedback from their audience rho = 0.517 (moderately correlated), p-value = 0.058. Our findings thus confirm Ahmed et al. [1] who reported on the crowd-reading skills more experienced DJs develop.

The data gained from the survey and podcasts indicated that DJs try different things during their performance to gain insights into what draws a positive or a negative reaction from the crowd. When asked what makes DJing interesting to them, one participant answered *"Challenging myself by improvising on the fly, testing the crowd reactions, and surprising the crowd with remixes, new music and throwback classics"*. DJs tend to play specific tracks at specific times to test the crowd's reaction to learn from it

and further develop their skills. Another participant answered "*The reception of the audience of previous tracks by the audience gives you an indication where you're at with them. Finally, the decision is largely based on intuition and which record ends up in your hand. I like that kind of destined feel to it sometimes and I think many DJs often just play what they feel like. This is also important for creating a connection with the audience if they see that you're actually enjoying what you're playing",* when asked about choosing a track during a performance. Additionally, another study participant answered that *"This is mostly about the spontaneous feeling I get while playing. But clearly the most important factor is the crowd's reaction. [...] Sometimes I'm really convinced about which track will work out best to follow up with. But then I'm noticing that the people are not feeling the record as intensive as me. Most of the time it works out because you get used to 'read dance floors'. But the decision is made within seconds and by trusting my feelings".*

Experienced DJs use the information they gather through testing the audience by reacting to how the crowd feels. They analyze how a specific performance was perceived by the crowd and their audience and try to develop their craft using these insights. One of the podcasts [27] specified how they analyze the performance after their gig. *"[Afterwards we talk about] how the night was, how the crowd was, the reactions. We're always reacting to the crowd. We never go to a party with a prepared set, we always react. Sometimes we play a very breaky set, sometimes a very straight set. Sometimes it's more housy. It's very diverse, because each night is different. After the sets we mostly or all the time speak about it and analyze what happened that night, how we liked it. Because we also play bad gigs. Not every gig is amazing."* We can conclude that DJs develop the skills to read the audience over time and by experiencing different situations during their live performances. They test the crowd and their own expectations by trial and error to train their sense for the crowd.

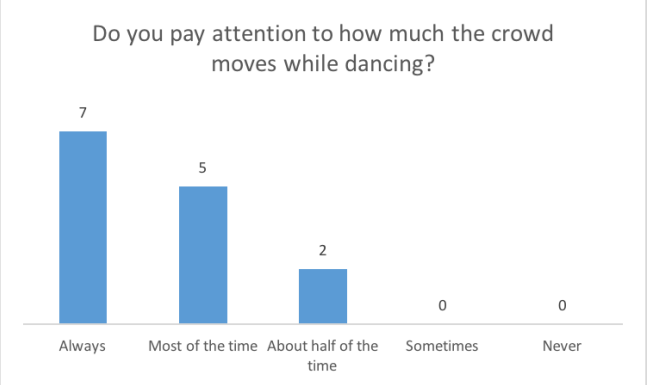

Figure 5. Answers given to Question 15 by the participants in the online survey

Information gathered by DJs

Another aspect we were able to assess through the survey was what kind of information DJs look for while observing the crowd. We identified the complexity of this interaction as previously discussed by Gates et al. [7]. The feedback they are focused on is based on the amount of people dancing, how much they are moving while dancing and where they are located in the club.

On one hand, 12 out of 14 live-performing DJs said that they always or most of the time pay attention to how much the crowd moves while dancing (see Figure 5). On the other hand, only eight out of 14 rated the location of individuals in the club as an extremely or very important information (see Figure 6). We used a paired Wilcoxon Signed-Rank Test to identify the significance of the difference. Our result indicates that how much the crowd dances was ranked statistically significant higher than where they are located in the club, p-value = 0.008.

The open-response questions support this insight. When asked about their motivation for DJing, one survey participant replied: *"The feeling when people dance to your music and create a good vibe in the club is incredible."* Another said: *"[...] At the end of the day I play to the majority in the crowd and want them to feel comfortable."* A quote taken from one of the podcast [27] likewise indicated the importance of keeping an eye on the dancing crowd: *"[...] If you get breaky or something, people just leave. Or they just don't get it. It's important to stay on that sound or to show something else. But also, you have to keep an eye on the dance floor."* Our findings indicate that DJs simply cannot see where individuals from their audience are located, therefore the movement of the visible crowd becomes one of the main insights they are able to gather.

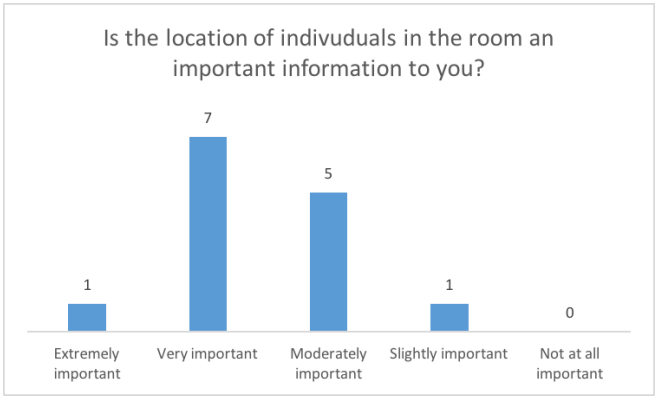

Figure 6. Answers given to Question 16 by the participants in the online survey

Factors adding to the difficulty of sensing the crowd

The observation in the club lead to insights into the context, setting and amount of work DJs face during their performance. The DJ's setup can be located in a variety of

spaces depending on the layout of the nightclub, with varying areas for their equipment. This can be challenging depending on the gear and tools they use to perform. The hardware can take up a lot of space and differs depending on the DJing style. During the observation, it became apparent that the DJ has to switch between an inside and outside world. The inside being defined by moments where they perform tasks including pre-listening to tracks or adapting the beats per minute ratio and the outside in which they glance over the dancing crowd, interact with their friends and fans or the club staff. Adding to the cognitive load, DJs also have to focus on their hardware. They have to make sure everything is working properly and keep an eye on their controller, spinning table, laptops, etc. Furthermore, nightclubs depict a dark environment with brightly colored spotlights, occasionally fog machines and visuals created by Visual Jockeys (VJs) or the DJ. A nightclub presents a loud environment in which the DJ uses headphones to listen to tracks before mixing them and match the beat of the tracks. The nightclub provides a stressful auditory work environment and adds to the cognitive load of the DJs. We can confirm the findings by Gates et al. [7] on problems DJs face while gathering information from the crowd such as being busy, working in a dark environment and being interrupted by multiple factors. Thus, we can say that DJs have limited amount of time, space and cognitive capacity to focus on other things such as a visualization during their performance.

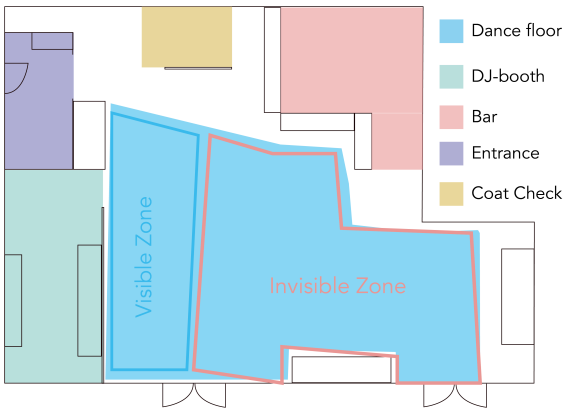

Figure 7. Visible & invisible zone in recreated floor plan from the observed club

The visible and invisible zone

Finally, during the observation we were able to identify two zones on the dance floor. The first zone contains the audience members visible to the DJ due to the closeness to the DJ-booth which places them within sight of the DJ (visible zone). Beyond the visible zone, it is difficult for the DJ to perceiving how many people are present and currently dancing. This invisible zone is out of sight to the DJ. Perceiving the crowd is thus limited to only a small subset of the audience. However, the ability to keep an eye on the dancing crowd would be a helpful piece of information to the DJ according to our findings. Making both zones visible to the DJ provides the opportunity to expand their horizon and provide them with deep insights into their audience.

Major findings:

- Reading the crowd is relevant for DJs
- DJs develop the skill of reading the crowd through experience
- DJs gather most information on how much the crowd is dancing
- DJs have limited time, space and cognitive capacity to process extra information
- The dance floor entails two zones: the visible and invisible zone

Requirements gathered for the visualization:

- The invisible zone should be made visible to the DJ to extend their perception
- The visualization should not be interactive or complex to read
- The visualization should be dynamic
- The visualization should encourage DJs to adapt their performance

4. VISUALIZATION

The data and process

Based on the established requirements gathered from analyzing the survey, transcribing podcasts and conducting a direct observation, we created a visualization using Processing[7], an object-oriented programming language commonly used for visualizations.

Figure 8. Wristbands holding Nearable boards by Estimote (left) & Sensor Tag boards from Texas Instruments (right)

[7] https://processing.org/

Prior to the development we considered different possibilities for a visualization, e.g. a tool that DJs could use to analyze their gig before a performance, during a performance or subsequent to a performance. We decided to focus on developing a visualization DJs could use during a performance, aiming to support DJs in learning and establishing the skill of reading the crowd's energy level over time.

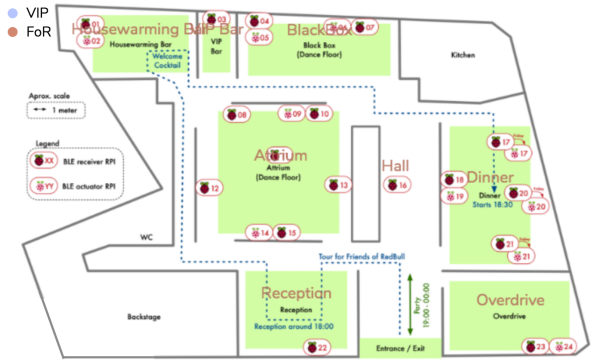

Figure 9. Layout of the club displaying different rooms, dancefloors and Raspberry Pi's

To develop a prototype as close to a real-life scenario as possible, we used real-world data[8] collected by Cabrero et al. [5] during the Amsterdam Dance Event[9]. During the event two types of wristbands embedding sensors were used: 800 of them contained Nearable boards by Estimote and 100 were fitted with Sensor Tag boards from Texas Instruments. The wristbands shown in figure 8 were designed by ByBorre[10] studio. During a timeframe of two nights, data was collected through a network of Raspberry Pi's which received Bluetooth Low Energy packets while the audience wore the wristbands in the club, measuring time, position, ambient and personal temperature and movement. The gathered data was pre-processed and stored in a CSV file. The file returns a float value between zero and two indicating how much people in the audience were dancing. We saw zero as being the lowest energy level and two the maximum energy level computed through the movement. To obtain a dataset focused on one dance floor, only the data from the dance floor in the room called Atrium was used for our visualization. The location of the Raspberry Pi's and individual dance floors are shown in Figure 9.

Visualizing the zones

To visualize the two zones (visible and invisible), we used the information in the data regarding which sensor was connected and thereby closer to which Raspberry Pi. We could thereby split the dataset into two zones. The sensors connected to the Raspberry Pi closest to the DJ booth were identified as zone one – the visible zone. The rest of the sensors in the room were registered as zone two – the invisible zone. The zone IDs were added to the data during the pre-processing.

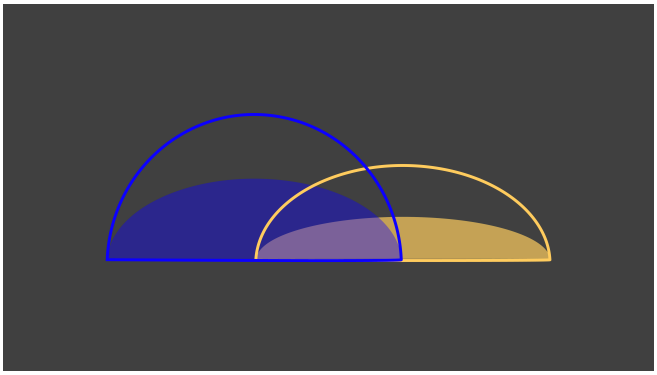

Figure 10. Visualization of energy level in the crowd, blue displays the visible zone, yellow the invisible

To create a visualization with low complexity, we developed a concept using abstract shapes. The entire crowd is visualized by a circle. With the goal in mind to display two zones, the circle was split into half circles (Figure 10). To provide DJs with a comparison of the two zones, we overlapped them in the center. The visible zone is displayed in the foreground in blue and the invisible zone in the back colored in yellow. The half circles display two main types of information's (Figure 11):

1. The height of the filled area represents the current average energy level of the crowd.

2. The height of the outer line represents the highest energy level up to the current point of the performance.

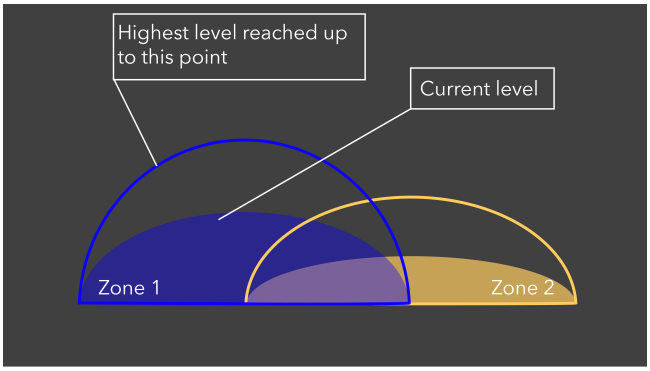

Figure 11. Visualization with explanation on zones and meaning of the height within the zones.

The visualization is not interactive, so DJs are capable to gather information on the crowd only by looking at the state

[8] The dataset, related code and other assets can be accessed on https://github.com/cwi-dis/CWI-ADE2016-Dataset
[9] https://www.amsterdam-dance-event.nl/
[10] http://byborre.com/

of the shapes. We developed the visualization to fit a mobile phone, a tablet or a small section on a laptop during a live performance.

Encouraging DJs to adapt their performance

The states of the zones enable the DJs to get a sense of the energy level of the crowd at any given moment in comparison to the rest of the performance up to this point. The height of the outline is updated each time the crowd raises the energy level above the previously highest point in order to encourage DJs to maintain the already defined max of their performance or even enhance it.

Limitations

Due to limitations in the collected data, we were not able to create a truly dynamic visualization. The preprocessed data we used only contained data of every ten seconds to categorize the energy level of each individual in the crowd. When averaging the energy level, we realized that updating the visualization every ten seconds could frustrate the DJs. The energy level of the crowd changes uniformly and rarely displays rapid changes, which would have led to a long waiting period with barely noticeable changes in the visualization. For our purpose, we decided to speed up the night and compress every ten seconds into one second.

To create a more realistic testing environment, music was added to the visualization. However, the added music was chosen after the data was collected and does not represent the original music of the night. The visualization is capable of detecting the beat and the outline pulsates slightly to its measurement.

5. EVALUATION

The evaluation was conducted using a qualitative approach. Our hypotheses for the evaluation are:

- DJs are able to understand complex data through our proposed visualization
- DJs are able to gain insights from the visualization
- DJs want to use the visualization during their own performances.

To test these hypotheses, we asked six DJs to evaluate the visualization regarding gained insights, the effective mapping of the visualization to the "real world" and acceptance, returning to our original research questions [16, 24]. We expected DJs to identify high and low energy levels as positive and negative feedback from the crowd and to associate them with the two zones. Throughout the test, we additionally assume that DJs will develop a better understanding of the visualization by gaining experience and training their understanding over time. Further, we want to gain more knowledge of additional requirements DJs hold towards the visualization.

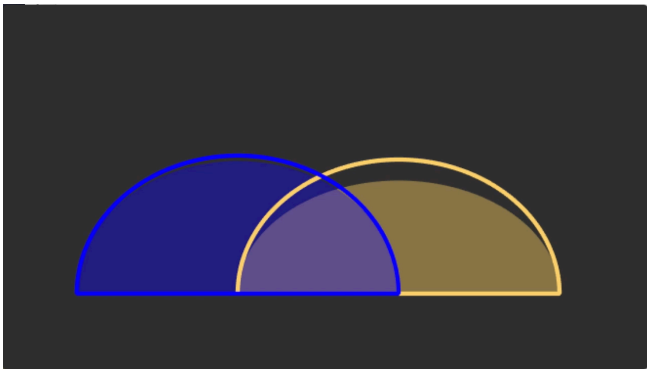

Figure 12. Image of the first simulation video of the visualization

The visualization was tested with each individual using Skype and Google Hangouts. The tests were carried out in German. All DJs have performed live. Four of them live in Germany, one in Austria and one in Ireland. Every session entailed a user test, following the think-aloud method, and a subsequent semi-structured interview. All conversations were recorded and transcribed. The transcript was later coded to identify categories of insights as well as analyzed on an individual basis to find specific requirements DJs hold towards the visualization, problems they had with it, features they appreciated and general ideas they had to improve it.

We introduced our project and explained the visualization using images of the visualization (see Figure 10) and the sensor wristbands (see Figure 8) as examples. The DJs were informed of the limitations. Then we asked them to imagine the following scenario: "You are performing in a club tonight. Before the event every individual in the club is handed a wristband with sensors. The sensors track how much people are moving, how high their energy level is at every point in time of the evening, and which zone they are currently in. Now it is your turn to perform. Imagine the visualization you are about to see is displayed during your performance."

Four different videos were displayed to the DJs, showing three different simulated stages of the evening.

Video 1: Both zones have a similar level, the invisible zone starts out strong but changes to a slightly lower stage than the visible zone. Overall the zones are both at a medium to high state. An example can be seen in Figure 12.

Video 2: The visible zone displays a much higher level than the invisible zone. Figure 13 shows an example of the video.

Video 3: Both zones are quite low, the visible zone performing a bit higher than the invisible one. At a certain point the visible zone peaks while the invisible zone stays low. An example can be seen in Figure 14.

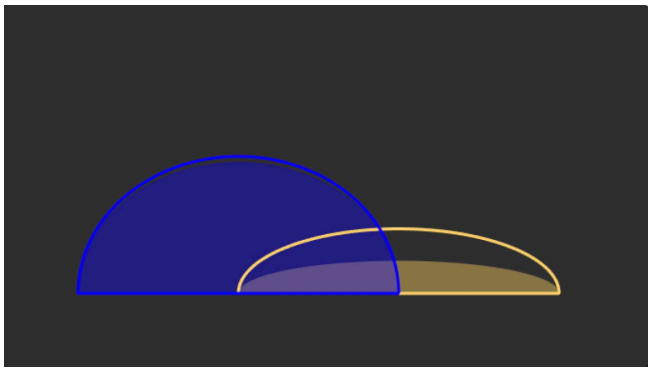

Figure 13. Image of the second simulation video of the visualization

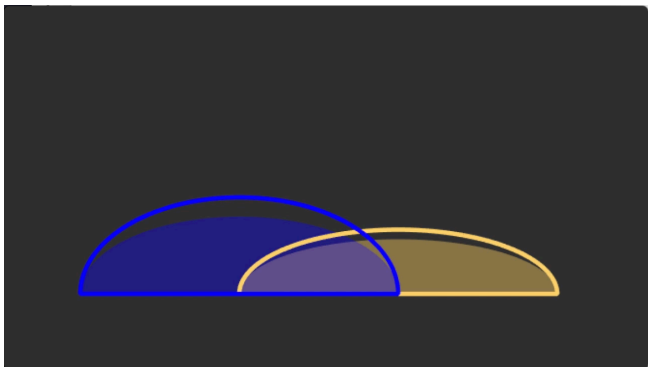

Figure 14. Image of the third simulation video of the visualization

In addition, we showed the DJs a fourth video displaying the same data as video 1 with different music to better understand the learning curve of our proposed solution.
The different videos were used to present the DJs with diverse scenarios of the crowd's energy level. During the evaluation we aimed to observe how the DJs map the visualization to the crowd and the performance. The different videos were used to get a sense of the DJ's capability to map the visualization under different conditions.

By open-coding the transcribed user tests, we were able to identify categories of insights DJs gained, problems they had with the visualization and feedback they provided. Both the think-aloud method and the semi-structured interview were openly coded resulting in two code books (see Appendix B). While coding we focused on gained insights, the effectiveness of mapping the information of the performance, whether or not they were interested in using the visualization during live performances and features they were missing.

5.1 Results

The qualitative evaluation of the prototype showed that DJs were able to understand the complex data. They were capable of using their understanding to gain extra information from the visualization. This lead to further assumptions and conclusions on the energy level of the crowd and ways to adapt their performance. Additionally, the DJs shared their interest in using the visualization and provided further information DJs seek in a visualization. We can confirm our previously stated hypothesis. Our findings are detailed below and summarized in section 5.2.

Understanding the visualization and gaining insights

During the think-aloud test we noted the categories of insights DJs were able to gain. They summarized the received information to draw conclusions and thereby sense the crowd and interpret why the crowd is reacting in certain ways. The gained insights were interpreted by mapping the visualization effectively to the "real world", meaning DJs connected the visualization with the energy level, the two zones and situations that occur during live performances.

All DJs but one were able to successfully understand the visualization. One DJ misunderstood the invisible zone as being outside of the dance floor. The DJs stated that the visualization was easy to understand subsequent to the explanation we gave and that it provided them with information they usually do not get during a performance. During the evaluation DJ 2 stated: "*You get a good set of information from it that you usually don't as a DJ.*"

By comparing the zones to each other DJs were able to read the visualization and categorize how the performance was going. DJ 1 found: *"They're going a bit crazy in the back now, the yellow circle grew pretty high. Both zones are at a similar height now, they both seem pretty well-filled. I would say the crowd is enjoying it."* The DJs determined how much the audience was enjoying the music based on analyzing how the zones were doing in comparison to each other. They additionally compared the four videos among each other to get a sense of how high or low the energy level could go to understand how they are doing at the moment. This also lead to our observation that DJs learn to read the visualization over time. The visualization aids them by comparison to gain more insights through experiencing different stages of the visualization leading to a learning curve.

The DJs were forming assumptions to what was happening on the dance floor. They drew conclusions concerning the layout of the club, how many people were currently on the dance floor, how many people were in which zone, what kind of music might have been playing, or whether the crowd was tired or not enjoying the music. DJ 2 observed: *"I would say that maybe there are just more people right in front of the DJ booth and a small part of the crowd is in the*

back. Maybe they are at the bar or there are some people that don't enjoy the music. But if everyone is in the front, then most of the people are satisfied." The DJs tried to filter out even more information than the energy level of the crowd. During the user test they continuously tried to understand why the visualization was changing in a given way. The DJs were also trying to match what is happening on the dance floor to the timeframe of the set. When the energy level was low, some of them assumed that it was at a low point in the set, while high energy resulted in the assumption that it was during a peak. DJ 5 concluded: *"I would say that this part was more in the middle of a good set or during a prime time."*

Additionally, they tried to understand how many people were in which zone. More steady levels led to the conclusion that the dance floor must be filled well, while drastic changes in the data were often considered as having a small number of people on the dance floor. DJ 6 observed in two different scenarios *"I can imagine that it means a lot of people are dancing at the moment. That's exactly what you notice as a DJ. The people that are in the front are going a bit crazier and you can see in the visualization that they are moving a bit more",* and *"It's not steady. Now they're going wild, the front had a peak. [...] Maybe it's only one person. I mean one person in the blue zone and one in the yellow and they're moving a lot and then stopping again."*

The overall information they were able to gain lead them to conclude that changing the style of the music and adapting their performance could be a great benefit to the energy level of the crow. DJ 1 explained: *"With this vibe you could definitely try to push it a bit more and then let it rip."*

Evaluating the visualization provided DJs with valuable information about the crowd, usually invisible to them during their performance.

Acceptance and needed additions

When asked if they would use the proposed visualization, all DJs said that they would find this tool useful or would want to try it out. However, all but one stated that it would have to be simple to use and not add more hardware the DJ has to carry around or worry about. DJ 6 explained: *"It would have to be easy to use, then I would try it and check it out right away. But if it's complicated and if I had to do too much stuff to get it running… I don't think I would. That would be too much of a hassle for me."*

Furthermore, the DJs stated that some additional information would be useful to them. Including a maximum scale in the visualization in order to contextualize the values was mentioned during the user testing by multiple DJs. They wanted to know how many people are currently in the room and on the dance floor in relation to how full the club is. During the think-aloud session we already noticed that some DJs were trying to guess how many people could be in the crowd and what this information means. They stated that the visualization should stay abstract and without numbers since they did not feel that there is enough time during a performance to analyze it. DJ 3 recognized: *"Especially during the performance you don't have that much time to analyze it in detail. I think the simple design is much better."*

DJs were also interested in receiving a more detailed analysis of their performance in the aftermath. They viewed this as beneficial to them and the club manager to get a better sense of how the night went. One DJ listed the benefit of being able to brag with a good night and high attendance numbers, thus being able to show promoters and bookers how well they performed.

Three of the DJs saw the visualization as most beneficial if it was integrated into the DJ software or hardware. The possibility was mentioned by two DJs to integrate the visualization into a smart watch. The smartphone, on the other hand, was viewed as not very practical since they do not use it during the performance, mostly do not have reception or Wi-Fi in the club and are worried about theft when they are too distracted.

We need to mention that four of the DJs were worried about the individuals in the crowd not wanting to use the wristbands and that it could be impractical to them. This should be kept in mind when organizing a nightclub event with sensors.

5.2 Summary

We can summarize the qualitative evaluation as follows: All requirements we defined in section 3.2 are met. The evaluation suggests that DJs are able to gain insights and enhance their perception of the audience's experience through our visualization.

The results indicate that DJs want to adapt their performance to satisfy their audience. All of the DJs viewed a low energy level in the visualization as a negative and a high level as positive feedback.

The DJs confirmed the requirement that the visualization should not be interactive or complex to read. They acknowledged the simple design as a functional carrier of the information. Most of them stated that adding numbers or text would lead to a too complex visualization that would require closer analysis. This would be impossible during their performance. However, they stated that they would benefit from an additional more complex visualization after their performance.

The DJs responded positively to the dynamic visualization and were capable of comprehending information in real time during the test.

Beyond our previously defined requirements, DJs stated that some additional information and functionality would be beneficial to them. They stated that having a scale which displays the maximum possible energy level in the visualization would help them add a relation. Further they were interested in how many people were in the zones compared to the amount of people in the club. Additionally, DJs declared that they would be interested in using the visualization, as long as it is easy to do so.

Major findings in the evaluation:

- The visualization aids DJs in understanding the complex data of the crowd's energy level
- The visualization provides additional information to their performance through the two zones
- DJs need additional information on the max energy level and the amount of people on the dance floor
- DJs want to use the visualization if it is easy to do so

6. DISCUSSION AND FUTURE RESEARCH

The qualitative evaluation demonstrated that the visualization is capable of extending the perception of DJs; the support system increased the insights DJs gain regarding the experience of the crowd.

To verify and build on the findings gathered in this study, the visualization should undergo additional testing in more realistic surroundings. The tests were carried out via video calls and the participants had to have a high degree of imagination during the user test because we asked them to envision a situation. To gain a more accurate understanding of the effective mapping from the visualization onto the crowd and their activity level, more real-life testing would be needed. We therefore propose live testing in a nightclub setting during DJ performances.

While we were able to gain useful insights into the DJ's perception, our study shows that many of the aspects that play a role into the DJ-crowd interaction cannot be reproduced in experimental surroundings. For example, some of the DJs found it difficult to draw information from the visualization without seeing and hearing the crowd on the dance floor.

A more realistic test situation could also result in a less positive response to the dynamic visualizations. During the user test DJs only had to focus on the proposed visualization, but in an actual performance scenario, they would have to combine reading the visualization with the cognitive load of mixing tracks and previously stated challenges they face during their performance. Testing the visualization under these trying circumstances is essential because the goal of the visualization is to lessen and not increase the cognitive load of the DJ.

It also has to be noted that the proposed visualization is dependent on the willingness of audience members to wear sensors, which is not a given. Therefore, the usability of the sensors for the audience should be considered prior to conducting additional studies.

Additionally, a more diverse and bigger test group would be beneficial to the study since sensing the crowd depends on individual DJs and their unique experiences. However, the evaluation did show that there were some common desires of the participating DJs to include functions into the visualization. Accordingly, we recommend adding a maximum scale and a visual representation of the amount of people in the crowd. Nonetheless, we do advise to keep these features abstract and to not add numbers or text due to the limited time DJs have during their performance for the analysis of the visualization.

Regarding logistics, the participating DJs proposed implementing the visualization within DJ-software, -hardware or using smart watches for the display. Research in the area of implementation and use cases should be conducted to further investigate technical possibilities; testing multiple implementations could lead to a thoughtful selection prior to further development of the visualization.

Another fact to keep in mind is that we collected, stored and preprocessed the data prior to inputting it into our visualization. This process would have to be implemented into a live-algorithm to make the tests during a live performance possible.

Finally, we learned that DJs were not only interested in a real-time visualization, but would additionally like to receive a more detailed analysis of the night after their performance. More research should be carried out and additional requirements should be identified to give DJs more options to analyze and learn from their performances.

7. CONCLUSION

Sensing the crowd can be challenging for DJs due to the pressure of performing live, recognizing visual and auditory influences and the need to multitask during performances.

To support DJs in better understanding their audiences, we developed a visualization which uses sensor data to display the energy level of the crowd. Our aim was to develop a solution which results in an increase of insights and it is effective and useful for DJs during live performances.

Our study established requirements DJs hold towards a visualization by analyzing a survey sent to DJs, transcribing a popular DJ podcast and conducting a direct observation during a live performance in a nightclub.

Based on these defined requirements we developed a visualization which displays the energy level of the crowd, divided into a visible and an invisible zone. The visualization provides DJs with abstract, quick to read information, meant to help the DJs establish the desired energy level of the crowd.

Finally, we evaluated the visualization individually with six DJs during a think-aloud test and a semi-structured interview. We found that DJs are able to increase their insights effectively through the visualization of sensor data and classified our proposed solution as usable.

Accordingly, we conclude that our goal of developing a visualization which supports DJs in sensing the crowd and understanding their energy level was fulfilled. In the future, the visualization should include the functions the DJs asked for. Furthermore, we see great potential for more research and development of the visualization and additional information DJs could profit from.

8. ACKNOWLEDGMENTS

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Appendix A

Welcome to the survey on DJ-crowd interaction.

Thank you for taking part in this survey measuring if and how DJs interact with their audience during live performances. The survey is run by the Centrum Wiskunde & Informatica Amsterdam and the University of Amsterdam in context of the Master thesis of Ronja Brettschneider. Today we will be gathering your thoughts and opinions in order to form a clearer understanding of the subject. This survey should take 15-20 minutes to complete. The answers you provide will be confidential and only used for the purpose of this research.

If you have any questions or concerns, feel free to contact us by sending an email to Ronja Brettschneider: r.j.brettschneider@cwi.nl

During the first part of the survey, we would like to ask you some questions about your career as a DJ and your personal style. We will also try to gather some of your habits while working and determine the genre you are most closely related to.

How long have you been DJing?

- ○ Less than 6 months
- ○ 6-12 months
- ○ 1-3 years
- ○ 3-4 years
- ○ More than 5 years
- ○ Not sure/don't know

If you had to pick a genre, how would you describe your sound on a general level? Don’t worry, you can give a more specific answer in question 3. (Multiple answers allowed)

- ☐ Breaks

- [ ] Chill Out
- [ ] Drum & Bass
- [ ] Dubstep
- [ ] Electro House
- [ ] Electronica
- [ ] Funk / R&B
- [ ] Hard Dance
- [ ] Hardcore / Hard Techno
- [ ] Hip-Hop
- [ ] House
- [ ] Indie Dance / Nu Disco
- [ ] Minimal
- [ ] Open Format
- [ ] Progressive House
- [ ] Psy-Trance
- [ ] Reggae / Dub
- [ ] Tech House
- [ ] Techno
- [ ] Trance
- [ ] Trap
- [ ] None of the above

Now you can elaborate. How would you describe your sound in your own words?

Do you perform live?

- ○ Yes
- ○ No

How long have you been performing live?

- ○ Less than 6 months
- ○ 6-12 months
- ○ 1-3 years
- ○ 3-4 years
- ○ 4-6 years
- ○ Not sure/don't know

How often do you perform live?

- ○ More than once a week
- ○ Once a week
- ○ 2 or 3 times a month
- ○ Once a month
- ○ A few times a year
- ○ Once a year
- ○ Less than once a year
- ○ Not sure/don't know

When was your most recent live performance?

- ○ Last week
- ○ 2-3 weeks ago
- ○ More than a month ago
- ○ 2-3 months ago
- ○ 4-6 months ago
- ○ More than 6 months ago
- ○ More than 1 year ago
- ○ Not sure/don't know

During this part of the survey, we will ask general questions about your performance habits and the interaction you have with the crowd while performing live.

How much feedback do you receive from the crowd?

- ○ As much feedback as possible, over 90%
- ○ A fair amount of feedback, about 70%
- ○ Some feedback, about 50%
- ○ Not too much feedback, about 30%
- ○ Barely any feedback, less than 10%
- ○ Not sure/don't know

Is understanding how the crowd feels during your performance important to you?

- ○ Very Important
- ○ Somewhat Important
- ○ Neutral
- ○ Somewhat Unimportant
- ○ Very Unimportant
- ○ Not sure/don't know

Do you adapt your performance according to the reactions of the crowd?

- ○ Always
- ○ Most of the time
- ○ About half the time
- ○ Sometimes
- ○ Never
- ○ Not sure/don't know

How difficult is it for you to sense the crowd’s reaction while performing live?

- ○ Extremely easy
- ○ Somewhat easy
- ○ Neither easy nor difficult
- ○ Somewhat difficult
- ○ Extremely difficult
- ○ Not sure/don't know

During this section, we want to explore the way you observe and experience the crowd during your performance.

Do you pay attention to how much the crowd moves while dancing?

- ○ Always
- ○ Most of the time
- ○ About half the time
- ○ Sometimes
- ○ Never

Is the location of individuals in the room an important information to you?

- ○ Extremely important
- ○ Very important
- ○ Moderately important
- ○ Slightly important
- ○ Not at all important
- ○ Not sure/don't know

Think of your most crowded performance: When did you feel most engaged with the crowd?

- ○ When more than 90% were dancing
- ○ When about 70% were dancing
- ○ When about 50% were dancing
- ○ When about 30% were dancing
- ○ When less than 10% were dancing
- ○ Not sure/don't know

Would you define the relationship with the crowd as collaborative or as competitive?

- ○ Collaborative
- ○ Sometimes collaborative
- ○ Mix between collaboration and competitive
- ○ Sometimes it’s competitive
- ○ Competitive
- ○ Not sure/don’t know

Having explored your interaction with the crowd, we would now like to learn a bit more about your personal experiences as a DJ. In this section, we are determined to find out some of the more existential factors contributing to the DJ’s performance.

We would now like to learn a bit more about your personal experiences as a DJ. In this section, we are determined to find out some of the more existential factors contributing to the DJ’s performance.

What are currently your main challenges as a DJ?

What makes DJing interesting for you?

Which factors trigger your decision to play a particular record during one of your sets?

When you perform live, do you control any other technological assets in the clubs (such as lights, visuals or any other features)? If yes, please specify.

- ○ No, I don’t control any other features while performing
- ○ Yes:

We are almost done - now we just have to gather some general information about you.

Please select your gender

- ○ Male
- ○ Female
- ○ Decline to state
- ○ Other (please specify)

Please select your age

- ○ Under 18
- ○ 18 - 24
- ○ 25 - 34
- ○ 35 - 44
- ○ 45 - 54
- ○ 55 or older

Which city do you currently live in?

Which country do you currently live in?

Choose one answer

What is the highest degree or level of education you have completed?

- ○ Some secondary education (high school)
- ○ Completed secondary education (graduated high school)
- ○ Trade/technical/vocational training
- ○ Some undergraduate education (college or university)
- ○ Completed undergraduate education
- ○ Some postgraduate education
- ○ Completed postgraduate education (masters or doctorate)
- ○ Other, please specify

Thank you for participating in the study!

Please provide us with your email address. Your information will not be given to

others and only used in context of this survey to either contact you with further questions or for you to take part in the raffle.

Please check the box below that applies to you.

- ◯ Contact me when you have follow up questions
- ◯ Contact me when you have follow up questions and add me to the raffle
- ◯ I don’t want to be contacted again, but would like to take part in the raffle
- ◯ I don’t want to provide my email address

Appendix B

Code Book

DJ-test

This code book contains codes used to analyze the transcribed raw textual data of the user tests and description about when to use them. The book is split into two sections; section 1 entails codes used to analyze the think-aloud user test responses, section 2 entails codes used to analyze the semi-structured interview responses.

Section 1: Think-aloud test

11 Codes:

- **Comparing to other video or image**

  Comment: Use this code whenever the DJs compare what is happening in the current video to the video before or the image we showed to them (videos contained segments of the prototype in different stages).

- **Comparing zones**

  Comment: Use this code when DJs compare the two zones to each other.

- **Desire to improve the set**

  Comment: Use this code when DJs voice the desire to improve the set or want to change something in the music to get a higher level.

- **How many people**

  Comment: Use this code when DJs wonder how many people are currently in the room or try to guess how many people are in the room.

- **Mapping info to dancing & activity of crowd**

  Comment: Use this code when DJs try to map the height of the shape to how much people are dancing or how active the crowd is at the moment; how much they enjoy it.

- **Mapping info to the music or how well the DJ does**

  Comment: Use this code when DJs try to map the seen information to how well the DJ is performing.

- **Mapping shape to amount of people**

Comment: Use this code when DJs try to map the shape to how many people are currently in the room.

- **Mapping shape to zone**

  Comment: Use this code when DJs map shapes to the zones of the crowd (visible and invisible).

- **Trouble understanding something**

  Comment: Use this code if DJs have a hard time understanding something or get stuck.

- **Trying to figure out why something is happening**

  Comment: Use this code when DJs try to guess why the crowd is high or low on the level.

- **Trying to match what is happening to time in the set**

  Comment: Use this code when DJs try to figure out from which point in time during the set the data came from, e.g. warm up, peak etc.

Section 2: Semi-structured interview

11 Codes:

- **Adding a max bar**

  Comment: User this code when DJs mention that they need some guidance on where the maximum value is.

- **Hard to compare. Live testing would be better**

  Comment: User this code when DJs have a hard time testing it without seeing the crowd.

- **I would not use this**

  Comment: Use this code when DJs state that they would not use the visualization during a live performance.

- **I would use this**

  Comment: Use this code when DJs state that they would use the visualization during a live performance.

- **Input from the crowd**

  Comment: Use this code when DJs consider the input they get from the crowd or when they state that it is important to them.

- **Integrated with DJ software**

  Comment: Use this code when DJs mention that the integration of the visualization into DJ software would be a good solution.

- **Other information needed**

  Comment: Use this code if DJs want more information on the visualization, e.g. numbers & letters.

- **Statistic after**

  Comment: Use this code when DJs mention that they would find an evaluation at the end of the night helpful with more information so they can track what worked well and what didn't.

- **Understandable**

  Comment: Use this code if DJs find the visualization understandable.

- **Wanting to test assumptions**

  Comment: Use this code if DJs mention the wish to test their assumptions about the crowd.

- **Worry about usability for the crowd**

  Comment: Use this code when DJs mention that they are worried about the usability for the people in the crowd (having to wear the wristbands).