IRMA (Interactive Real-time Measurement of Attention). A method for the investigation of audiovisual computer music performances.

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ABSTRACT

IRMA (Interactive Real-time Measurement of Attention) is developed as a measuring apparatus to investigate performances of audiovisual computer music in situated contexts. It provides devices and software to monitor the audience's focus of attention during the course of the performance. The explorative method involves interpretation by collating quantitative empirical data alongside qualitative data gathered by the means of questionnaires and interviews as well as musicological analyses.

Besides being designed as a tool for providing composers and performers in artistic research processes with empirical feedback on how audiovisual materials or performative acts are perceived by the audience, IRMA delivered empirical groundwork for general aesthetical considerations. In this paper, both approaches towards research are exemplified on the basis of two performances of audiovisual computer music. The results demonstrate how particular artistic concepts have been perceived by the audience, and also indicate general insights into the perception of audiovisual compositions. IRMA has so far been used and evaluated with eight computer music performances in three concerts.

1. INTRODUCTION

1.1 Background

The aim of this paper is to describe the exploration of a new method for the investigation of audience attention in audiovisual performances. In a second step, findings are presented that exemplify different methods of processing and interpreting the collected data. Research was undertaken as part of *Gamified Audiovisual Performance and Performance Practice (GAPPP)*[1], an artistic research project currently undertaken at the Institute of Electronic Music and Acoustics, Graz/Austria. At GAPPP one important research objective is to investigate the audience perception of gamified[2] – or more generally *ergodic* [1] – audiovisual performances with methods from the social sciences and musicology. The goal is to inform composers and performers of electronic audiovisual music and give them a better understanding of the perception of their works. A main interest lies in determining the elements that attract the audience's attention in the complex situation of an audiovisual performance of contemporary computer music. In a second step a better understanding of the causal conditions of such points of attraction is sought.

The starting point for *Interactive Real-time Measurement of Attention (IRMA)* were so-called attention triangles introduced by Marko Ciciliani and Susanne Sackl-Sharif in the early stages of the GAPPP project. The intention was to operationalize initial research questions of the project regarding audience perception and feedback for the composers and performers.

The audience at the lab concerts was asked to mark a spot representing their principle focus of attention within a three-dimensional space with the dimensions: *Music/Sound – Visuals – Performer*. By placing the mark in the triangular field, different weights (e.g. "between visual and sounds") are indicated. When the mark is placed in the center of the triangle, all three dimensions are weighted equally. If the attention lies predominantly on the performer, the mark would be placed at the bottom right corner. In boxes next to the triangles subjects had to provide additional verbal feedback and to indicate which moment of the performance they were referring to.

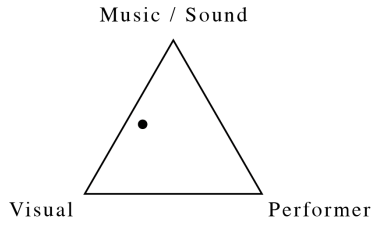

Figure 1. Three-dimensional Attention triangle.

The triangular shape was assessed as a functional representation as it allows measuring values between all three relevant dimensions by placing marks in one single diagram. Using bipolar scales for example would have made necessary several different scales. Furthermore, putting marks in the triangular diagrams in the questionnaires was thought to be more intuitive and spontaneous and therefore less interfering for the audience (at a concert situation) than giving verbal feedback.

The triangles have been used in the first questionnaires of the project in a printed and therefore static fashion (see Figure 1). While the data that was collected by means of this method provided first indications, a number of limitations and drawbacks became apparent:

(1) As subjects only rarely made precise indications as to which moments of the performance their marks refer to almost no information could be gained on how the attention changed during the performance.

(2) For the same reason, it has been difficult to impossible to assign the very subjective comments and marks of the subjects to certain moments of the performance and to compare the marks of different subjects.

[1] GAPPP is funded by the Austrian Science Fund FWF as part of the PEEK program for artistic research, nr. AR364-G24. For a detailed description of the project please see www.gappp.net

[2] For a brief description of the underlying understanding of gamification also see www.gappp.net

1.2 Premises

To solve these problems and obtain more detailed data, a method comprising custom technological apparatuses was developed that allows for the retrieval of real-time information of audience attention. Experiences made in GAPPP and research in the field (see *Context*) suggested some premises for the development of IRMA:

(1) Research on perception of music operates often in lab experiments with systematically varied short audiovisual fragments that led to a plentitude of findings [2] [3] [4] [5]. However, these results are typically of little significance to the experience of time varied complex aesthetic relationships, that are characteristic for audiovisual performances in a concert setting. For the research presented in this paper, audience experience shall be understood as perceiving artworks in situated concert contexts. Nevertheless, one has to bear in mind that the complexity of the situated concert experience means that the setup is not fully controllable and the parameters are not fully modifiable in a systematic way [6].

(2) The use of consumer products like tablets and the development of open source software[3] is not only seen as an idealistic alternative position towards proprietary high-end lab setups. It is also understood as a good scientific practice to avoid *black boxes* of proprietary high-end apparatuses and attain a more detailed understanding of the materiality of the measuring devices by constructing them by oneself. In doing so their materiality and agency can be rendered more transparent, scientifically describable and discussable. Also, such devices are open for replication. So ideally a toolkit of this kind can be used by others for their own investigations in artistic research projects.

(3) Measuring the focus of attention of subjects perceiving an audiovisual performance first-hand does not say anything about the subjective aesthetic experience. Interpretation can only reveal meaning once this quantitative data is brought into a context of musicological analyses of the musical performances and qualitative feedback by the subjects.

(4) Measurement affects subjects by directing their attention to the apparatus. In this way, their attention is interfered. Generally measuring without interference is impossible [7] and especially in the case of *IRMA* the effect cannot be avoided completely but can only be minimized.

1.3 Context

Next to a large body of studies in music psychology investigating various aspects of how traditional Western art music is perceived [8] and experimental aesthetics [6], lately an interest in investigating the reception of characteristics of contemporary and electro-acoustic compositions is evident in several publications. In some instances, they also adopt a situated perspective, study artworks in performative contexts and stem from artistic research and musicology. For example, in a study conducted by A. Çamci [9] subjects listened to two electro acoustic pieces and gave semantic feedback on associations on narrativity in real-time. In recent experiments undertaken at the Royal Northern College of Music a specially designed app was used in a concert situation. The app allowed for tapping on displays of smart phones to indicate the moments at which subjects perceived section boundaries in contemporary music [10]. Video analysis of concert recordings was conducted with computer vision algorithms to observe embodied and distributed musical experience [11]. Besides being situated and declaring whole artworks as objects of research, the mentioned studies allow to match measurements or feedback to specific parts of the performance. The method IRMA is located within this field of research.

2. MEASURING APPARATUS

2.1 Device hardware and application

An Android application for touch tablets[4] was developed that lets individual audience members indicate the focus of their attention throughout the performance. They do so by placing their finger within a designated triangular field on the screen. The coordinates of the finger positions are sent continuously via Open Sound Control (OSC) over a network connection to a host application. The device application is fully configurable by the researcher and can run on almost any display size and resolution.

Cases exposing only the triangle interface were produced by laser cutting cardboard. This design decision was made to provide a haptic feedback to the users by physically marking the boundaries of the touch interface. In this way, it is operable in a more intuitive way and less attention is drawn to the apparatus as the audience operates the device.

2.2 Host application

The host application allows to operate the collection of data in the concert situation. This takes place by communicating with the device apps of all connected tablets, by naming, starting and stopping the recording as well as defining the time interval for measurements. The incoming OSC data sent by the device apps is stored in JSON-files on the host computer. The data-structure of the JSON-files is simple, it contains a time stamp in milliseconds for synchronization, the ID of the sender (the device operated by the respective subject), the current coordinates of the index finger in the triangle and the name of the recording:

```
{
  "timestamp": 500,
  "senderId": 1,
  "x": -0.14687499403953552,
  "y": 0.2222018837928772,
  "Recording": "Kilgore"
}
```

Real-time visualizations of the incoming data in the host app allow observations and monitoring by the researcher in live situations.

[3] The GIT of the project can be found at https://github.com/asa-nerd/IRMA

[4] Ten Samsung tablets of the type Samsung TAB A where used.

2.3 Analysis application / Knowledge extraction

A third piece of software developed in Java and Processing allows to load the JSON datasets collected in the preceding steps and perform calculations and visualizations. What follows is a concise explanation of the calculations and visualizations that this software performs.

2.3.1 Calculations

Activity: Activity is calculated by computing movement (distance) for each measuring point compared to the last point in time. This is done for every measuring point for each subject and also for the whole sample.

Average focus of attention: The mean of the position of all points (representing all subjects) at a given time is calculated and displayed in the triangle (see Figure 4). It shows the *average focus of attention* at a given time.

Deviation of attention: In a second step the distances bet-ween the *average focus of attention* and the focus of attention of the individual subjects are calculated. They are displayed by a line in the triangle. From these distances, the deviation is calculated. *Deviation of attention* is intended to be useful for finding sections in performances, in which the audience's focus of attention collectively shifts to certain audiovisual aspects or in which attention is divergent.

2.3.2 Visualizations

Activity: Joint activity of all subjects at each measuring point can be displayed linearly in terms of vertical lines on a time axis (see Figure 3). The resulting structure shows the amount of activity over time and can reveal parts and moments in which the *focus of attention* shifts.

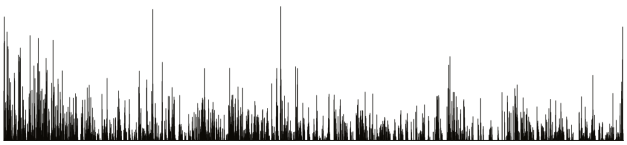

Figure 3. Activity over time for *Kilgore* by Marko Ciciliani.

Spatial representation: The datasets are displayed as points in a triangle according to the finger positions and movements of the corresponding subjects over time. The recorded timecode and coordinates data is used for the corresponding calculations (see Figure 4).

Color coding: Each dimension of the previously defined three-dimensional attention space is given a basic color of the RGB color space. The space between the poles of the three dimensions is accordingly filled with gradients. Now each position in the triangle is represented by a distinct color (see Figure 4).

[5] GAPPP covers a larger range of research interests – for example questions dealing with gamification or performance. For this paper only the data relevant for *IRMA* was taken into account.

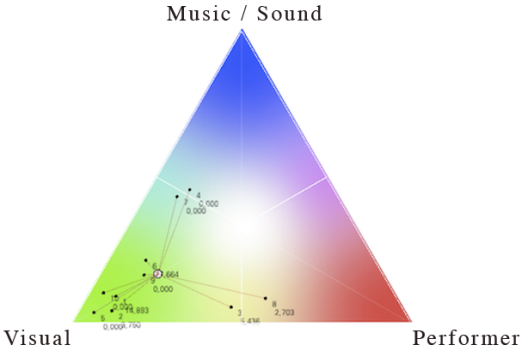

Figure 4. All Points, calculated *average focus of attention* and distances of points from average leading to *deviation of attention*. Color coding the spatial positions later allows a translation to a linear visualization.

Linear representation: The introduction of color coding of spatial positions offers the possibility to visualize the data of individual subjects and the *average focus of attention* of subjects in a linear way on a time axis. This linear visualization allows for encoding the *deviation of attention* in the vertical dimension. The resulting bars vary in width: the lower the vertical height the more uniform is the measured focus of attention among subjects at a given time (see Figure 5).

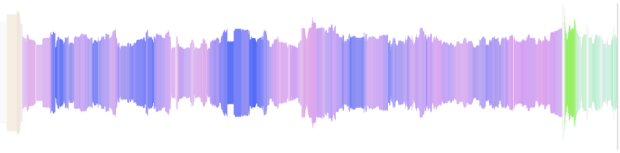

Figure 5. Visualization of a performance of *Tympanic Touch* by Marko Ciciliani. The vertical height of the bar represents *deviation of attention.*

2.4 Contextualization

Experience with questionnaires and interviews in GAPPP show the necessity of analyzing the collected quantitative data by correlating it with aesthetic and perceptive phenomena of the actual performance and take qualitative feedback into account.

Video analysis: To analyze the quantitative data in the context of aesthetic phenomena of the performance, video footage of the concert can be displayed in the analysis app. A timeline makes it possible to scrub through video and qualitative data and its visualizations simultaneously. This allows for a method of finding significant moments by visually browsing video and visualizations at the same time.

Qualitative feedback: qualitative data is collected in large amounts through interviews and by questionnaires at the lab concerts of the GAPPP project. The data is transcribed and later analyzed with MAXQDA.[5] Qualitative data from questionnaires as well as interviews and visualization are collated manually and supplement the visualizations.[6]

[6] A detailed visualization covering the complementary perspectives in analyses is beyond the scope of this paper but can be accessed under https://github.com/asa-nerd/IRMA/blob/master/documentation/analysis/AnalysisKilgore.pdf

3. STUDIED COMPOSITIONS / PERFORMANCES

3.1 Common characteristics

The application of *IRMA* and thereby some different ways of mining and interpreting the gathered data shall be exemplified by the research on two audiovisual computer music compositions. Both of them have been commissioned and composed for GAPPP.

Common characteristics of the researched compositions are that they comprise audio as well as visual material. They are ergodic (or gamified) in different ways and comprise one or more human performers. Both pieces include virtual realities to different degrees and bodily representation in virtual space or a first-person view projected on a screen that suggests a bodily presence in virtual space. One piece comprises a VR headset for the performer.

3.2 Experiment

Research was conducted in two lab concerts (n = 31 and n = 35) with audiovisual performances at the IEM Graz. At each concert, ten subjects were equipped with *IRMA* devices. The participants were instructed to move their index finger in the attention triangle throughout the performance according to their current impression of where their focus of attention lies at the moment. Also, questionnaires had to be filled out covering the participants personal background as well as various aspects of the subjective experience of the performance. The latter were mainly measured with Likert scales. All subjects were asked to fill out printed static attention triangles manually in the questionnaire and to make notes at which point in time during the performance they made their entry. The setup for the measuring apparatus *IRMA* was as shown in Figure 6.

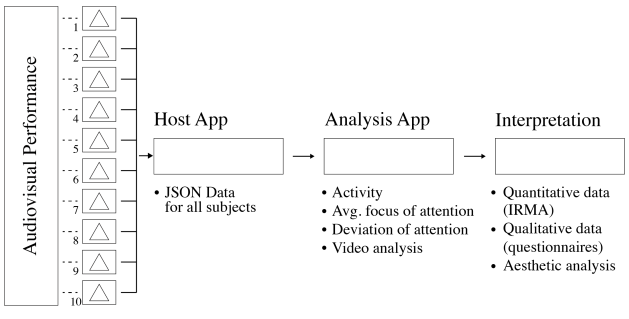

Figure 6. Work- and dataflow at concert situation

3.3 Marko Ciciliani: Kilgore

3.3.1 Characteristics

Kilgore is a composition for two performers playing game controllers and instruments. It comprises five parts of which two are situated in first person open world game environments in which the performers interact with sonic agents. In this way, they perform the audiovisual gestalt of the parts. The composition comprises tasks to fulfill for the performers that guide them through the open world. In the other three parts (Preludus, Interpaidia, Postludus) the performers play instruments on stage.

3.3.2 Patterns of activity

In the already mentioned study [11] manual tapping on a touch display was used to mark sections in the piano piece by Ligeti. With IRMA, *activity* (describing the amount of change in the *focus of attention*) is interpreted to investigate significant moments in a performance:

(1) Shorter peaks of activity potentially indicate that changes or transitions in phenomena are perceived. If short peaks are observed, subjects are believed to adjust to a new perceptual situation. Activity goes back to a lower level after this.

(2) Different parts of the observed pieces can show different patterns of activity (see Figure 7).

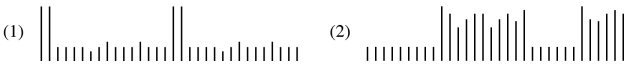

Figure 7. Patterns of activity. High degrees of activity of subjects indicate shifts in attention.

The tracking of distinctive situations of high activity could be the groundwork for further analyses and feedback for composers and performers.

3.3.3 Combining and complementing analyses

In a second layer, activity is set in relation to the *average focus of attention* and *deviation of attention* of subjects. The corresponding bar graph shows varying characteristics over the course of a performance (see Figure 5-2). Further layers take into account qualitative feedback gained by questionnaires and interviews as well as aesthetic analyses. Unlike the studies referenced before, the method IRMA follows a complementary approach by collecting time-accurate quantitative data for attention and collating qualitative semantic feedback to that data (see Figure 8).

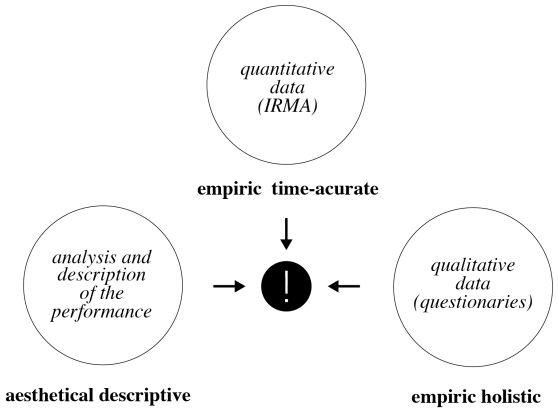

Figure 8. Complementary approach for IRMA

3.3.4 Specific feedback for composers and performers in artistic research

IRMA's empiric data provides feedback to composers and performers about which parts and materials of a performance are perceived disparately by the audience, and which are perceived as belonging together. A central research interest in the design of the method lies in investigating if aesthetical intentions of composers and performers translate to the audience. In case of *Kilgore* composer Marko Ciciliani for example stated:

"What I wanted to achieve [with Kilgore] was a form of several parts where the focus shifts. In the 'game parts' one focuses on 3D reality. But then there are these interludes […] where they [the instrumentalists] just take their instruments and play practically in a chamber music way. And then of course attention shifts a great deal to the performers."[7]

Exploring the data collected with *IRMA* at the concert performance of *Kilgore* shows that Ciciliani's intention to compose different sections with different points of focus of attention has generally translated to the audience. Figure 9 shows the *average focus of attention* calculated for the 5 parts (marked A1 to A5) of *Kilgore*. The attention for the 'game parts' in 3D reality (marked A2 and A4) lies between the dimensions *Music/Sound* and *Visual*. For the parts in which the performers play their instruments on stage (marked A1, A3 and A5), the attention is closer to the dimension *Performer*:

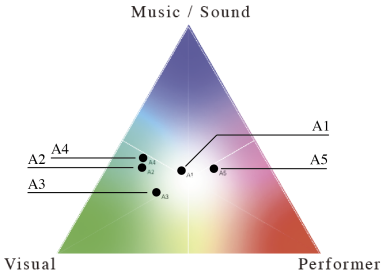

Figure 9. Average focus of attention for all 5 sections of *Kilgore*. Section 2 and 4 are in 3D reality and in sections 1,3 and 5 the performers play their instruments (n=5).

That means however that the average focus of attention is shifted only to the center (where the attention is balanced) and not fully drawn to the dimension *Performer*. A closer look also reveals that in part 3 (A3), the average focus of attention lies closer to the visual dimension than the other two parts with performers playing instruments (A1, A5). Taking phenomena of the performance and aesthetics into account, the analysis provides further insights: In part A3 one performer just produces feedback on the guitar generating an ambient sonic layer melting with the visuals. Simultaneously a cinematic sequence (a cut scene) is projected that draws the *focus of attention* to the screen with the performers just accompanying that scene. The result is, that the perceived roles of the performers are not as distinct as in parts A1 and A5. Conducting research with *IRMA* reveals that shifts in attention occurred between parts of *Kilgore*. Aesthetic analyses can provide a framework for interpreting the data and can inform about how the performance and the material is perceived.[8]

3.3.5 General insights: Visual first?

Cognitive research on audiovisual perception has shown a dominance of the visual domain [12]. Empiric data collected of *Kilgore* by means of *IRMA* shows on several occasions that when visual elements are introduced to the performance, initially they tend to attract attention and dominate perception. Gradually this focus decreases again and sounds as well as aspects relating to the performer "re-enter" the focus of attention.

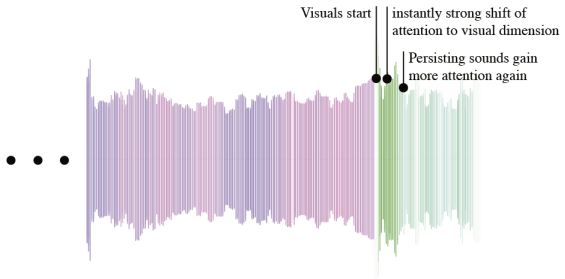

Figure 10. Empiric data visualizing the shift of attention to visuals at the end of *Tympanic Touch (n=10)*.[9]

A significant example of this observation is the last section of *Tympanic Touch*, a composition also by Marko Ciciliani (see Figure 10). Here visuals are added to the performance only after about ten minutes. As the projection starts, the average focus of attention instantly shifts close to the extreme pole of the dimension *screen,* coloring the graph deep green. Other dimensions almost cease to play a role. After a short while however, the perception of the subjects seems to have adjusted to the new situation and the indicated perception balances out. While the visual aspect still dominates, other stimuli regain attention – the average focus of attention moves to locations between *screen* and *sound* (turquoise color).

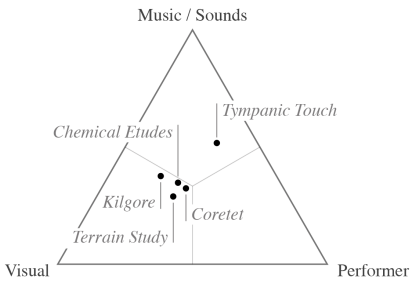

Figure 11. Average focus of attention for whole performances.

[7] Cited from an interview (March 1st, 2018) that was led with the composer before the concert at the GAPPP project.

[8] A detailed visualization covering the complementary perspectives in analyses is beyond the scope of this paper but can be accessed under https://github.com/asa-nerd/IRMA/blob/master/documentation/analysis/AnalysisKilgore.pdf

[9] Performance by B. Lüneburg and M. Ciciliani on February 28th 2018 at IEM, Graz.

Calculating the *average focus of attention* for entire audiovisual performances also shows a slight but consistent shift towards the visual dimension (see Figure 11). For comparison, *Tympanic Touch* is also shown.

3.4 Christof Ressi: *Terrain Study*

3.4.1 Characteristics

In this composition, an audiovisual setup is used which combines virtual reality with the physical performance environment that is inhabited by the performer and the audience. For the audience, musical form, sonic characteristics and space emerge from the ongoing interaction between performer and virtual sound agents. As sound and sound-oriented interactions of the performer become parameters that increasingly contort the topography of the virtual environment the virtual performance space becomes more and more estranged from the familiar logic of the physical world. It becomes a world whose materiality changes as the result of the sonic interactions of the performer.

3.4.2 Investigating special aesthetic situations

Special aesthetic concepts and implications of compositions bring up the necessity for a way of analyzing collected data that takes these into account. In the case of *Terrain Study* hypotheses are derived from qualitative data gathered in an interview with the composer and from questionnaires filled out by the audience. Quantitative data from questionnaires suggests a high amount of merging of materials (audio, visuals and game-elements).[10] At the same time, the composer reported in the interview, that his idea was that with the audiovisual experience no dimension of attention will dominate but that the attention would fluctuate.[11] Analyzing data from IRMA shows that the color coding of the *average focus of attention* tends to white for the first half of the performance (see Figure 12).

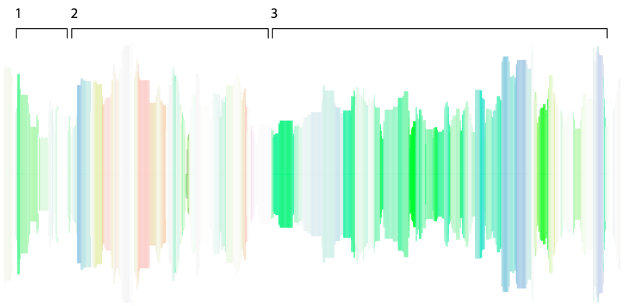

Figure 12. *Average focus of attention* and *deviation of attention* for *Terrain Study (n=10).*[12]

This indicates that the *average focus of attention* lies almost in the middle of the three-dimensional space and is compliant with the aesthetic idea of the composer. The calculated *deviation of attention,* however reveals that individual subjects have rather diverse focuses of attention. This implicates that although subjects stated in questionnaires that different elements merge, they still seem to have shifting focusses of attention throughout the performance and in this way different ways of perceiving it. This also goes along with Ressi´s idea of a fluctuating focus of attention.

According to the previously described visual dominance in the attention of subjects, with *Terrain Study* the *average focus of attention* at the beginning also tends to the visual side (see Figure 12, Section 1). After that, the average attention focuses more strongly on the performer (red) emphasizing her special role in this piece, which also becomes more extroverted as the piece progresses. After about half of the performance the visual dimension (green) becomes dominant again (see Figure 12, Section 3). This confirms that the aforementioned convolution of the virtual space towards a dystopian environment, getting more abstract and "weird" and in this way attracts attention.

Apart from findings based on quantitative data, the importance of this process for the aesthetics of *Terrain Study* is further underlined by the questionnaires in which subjects related frequently to it and often mentioned the "strange" transformation of the virtual environment. Unexpectedly they gave positive ratings to otherwise rather negative adjectives describing the emotions/associations they had at the performance:[13]

Subj. 6-9: dangerous (+); tense (+)
Subj. 6-28: death (+); nightmare (+); helpless (+);
Subj. 6-33: angst (+); confusion (+)

This example of collating IRMA data with aesthetic reflections and qualitative data shows a surprising finding. The strong relation to the visual domain in the second half of the performance seems unusual, as from a compositional viewpoint the VR World more and more becomes increasingly dependent to the logic of sound and the violin of the performer.

4. CONCLUSION AND DISCUSSION

The exemplification of the method *IRMA* demonstrates a flexibility that allows for different approaches in tackling specific research topics. A key step is to contextualize quantitative data collected with *IRMA*. In the case of GAPPP this can be means of aesthetic considerations, musicological analyses, qualitative feedback through questionnaires and fieldwork. In this way, strengths of *IRMA* like time-accurate quantitative measurement of attention can benefit from a more holistic qualitative feedback of

[10] Mean 4.3 (median 5) on a 5 pole Likert scale that asked subjects how much they agree with the statement „*The game elements melt into a unity with visual and auditive elements.*"

[11] "I can't tell exactly where the attention lies, ideally it is fluctuating." Interview with the composer (March 1st, 2018).

[12] Performance by B. Lüneburg on September 27th 2018 at IEM, Graz.

[13] Subjects answered to the question "Which spontaneous emotions/associations did you have while the first artwork was presented?" and marked the adjectives as positive (+), negative (-) or neutral (~).

subjects. It was shown that empiric insights provided by *IRMA* can offer feedback for composers and performers on how material configurations are perceived. Further, the described observations show empirical indications for effects of visual dominance in a situated concert setting of audiovisual music. Surprisingly feedback by participants given in questionnaires indicates, that they often didn't feel distracted by operating *IRMA*. They frequently even stated that the device made them reflect more consciously about how they perceived the performance.

For statistical calculations of significance or chi-squared tests a larger number of subjects (>30) would be needed. This could be achieved by presenting video material of the performances to subjects by online services like Mechanical Turk [13]. Subjects could respond on their trackpad. A disadvantage would be that the situatedness and first-hand aesthetic experience would be lost.

Alternatively, to overcome being limited to ten devices, a version of the app could be developed that is operated by audience members on their own smart phones (as it was in [10]). A drawback of this adaption would be that the apparatus would be less standardized as participants would operate with different sizes of displays and without haptic feedback by the enclosure.

For such a larger sample, performing an analysis looking for clusters of attention could be insightful. The data of subjects populating the found clusters might be further be enriched with sociodemographic background information from the questionnaires to characterize certain groups within an audience.

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