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CHAPTER 2

EXPERIMENT DESIGN AND DATA ANALYSIS

EXPERIMENT DESIGN

The "cognitive revolution" of the 1950s brought about new research trends in the fields dealing with the human mind. In psychology, this took the form of a counter movement against behaviorism (Miller 2003: 141). Striving to go beyond the study of observable behavior, cognitive psychologists placed emphasis on brain activities by investigating representations of sensory stimuli and how these representations are processed by various mental faculties. In its rejection of the prevailing divide between mind and matter, a key premise of the cognitive revolution was that "the mental world can be grounded in the physical world by the concepts of information, computation, and feedback" (Pinker 2003: 31). Psychology was not the only field to be greatly influenced by this movement.

> While experimental psychologists were rethinking the definition of psychology, other important developments were occurring elsewhere. Norbert Wiener's cybernetics was gaining popularity, Marvin Minsky and John McCarthy were inventing artificial intelligence, and Alan Newell and Herb Simon were using computers to simulate cognitive processes. Finally, Chomsky was single-handedly redefining linguistics. (Miller 2003: 142)

A main source of momentum for the cognitive revolution was its interdisciplinary relevance. The pioneering cognitive psychologist George Miller lists six disciplines which spearheaded this movement: psychology, linguistics, neuroscience, computer science, anthropology and philosophy (143). Unifying these fields through theoretical models, cognitive science thrives on "the diversity of outlooks and methods that researchers in different fields bring to the study of mind and intelligence" (Thagard 2014).

As the philosopher Paul Thagard puts it, "[a]lthough theory without experiment is empty, experiment without theory is blind" (2014). For the current study, which situates electronic music as an object of cognitive experimentation, I have utilized psychology, linguistics and computer science in the design and the analysis of the experiment, and philosophy to bind theoretical perspectives with experience. By embracing a truly interdisciplinary methodology, this study brings electronic music into a cognitive science framework.

Analytical Approaches to Electronic Music

Such fields as psychoacoustics and music psychology, which have been dealing with sound and music since ancient times not simply as physical but also as *auditory* phenomena, gained a significant prominence in 20th century as a result of the aforementioned shifts in the scientific paradigm. As the cognitive revolution spread to the study of environmental sounds in the latter half of the century (Bartlett 1977; VanDerveer 1979), experiment-based studies on perception and appraisal of music also started to gain prominence. From that period on, countless studies have offered remarkable contributions to our understanding of auditory and musical experiences. The current book will refer to a wealth of modern studies of auditory psychology in the ensuing chapters.

Analytical methods which deal with the experience of electronic music are as old as the genre itself. Pierre Schaeffer demarcated the pioneering style of the French studio, namely musique concrète, by describing theoretical constructs, such as *sound objects*, and listening modes, which in themselves can be considered as proto-analytical devices. Long after their postulation, Schaeffer's theories are still central to many analytical debates on electronic music. However, the *post-Schaefferian era* (Demers 2010: 14) starting in the 1970s has produced its own array of analytical approaches towards electronic music. In novel discussions on the ontological and experiential characteristics of electronic music, many researchers and composers have proposed new perspectives informed by semantics, perception, aesthetics and technology (Emmerson 1986; Bridger 1989; Wishart 1996; Smalley 1997). Furthermore, scholarly work adopting experiential approaches in the analysis of electronic music have gained a significant impetus more recently (Windsor 2000; Field 2000; Simoni 2006).

A common method to gather phenomenological insight on a particular topic is to conduct subject-based studies. But as the composer Leigh Landy states, although listener-based research in electronic music is not unprecedented, it is "the exception rather than the rule" (2007: 39). The amount of such studies focusing exclusively on electronic music is dwarfed by the existing research on the cognition of instrumental music. Below I will discuss a number of studies that enquire into various aspects of electronic music by incorporating listening experiments.

In one of the earliest examples of such studies, the researcher Michael Bridger conducted an analytical investigation of electronic music based on experience reports from listener groups. Using short sections of five electronic music pieces that heavily incorporate the human voice, Bridger administered repeated listening sections to acquaint the participants with the works. This was followed by discussion sessions with each listening group (Bridger 1993: 298), where he annotated the comments on dynamic level traces of the pieces printed on A4 paper (1989: 147). This method, although lacking statistical control as Bridger points out, yielded several interesting insights such as the listeners' attentiveness to the human voice, conventional musical instruments, and spatial movement of sounds (159).

In his studies on listening behaviors in electronic music, the researcher François Delalande was also one of the first scholars to adopt a subject-based experimental model. In a study of "external inquiry" (Delalande 1998: 22), Delalande and the composer Jean-Christophe Thomas requested eight subjects with varying expertise in electronic music to listen to a short movement from Pierre Henry's *Sommeil* (24). Thomas later surveyed the subjects in the form of a "relaxed interview". Delalande describes his research goal as a search for consistencies "not directly in what listeners hear but in (…) their listening behaviours" (23). Accordingly, he concludes that there are coherences within separate listening behaviors which represent analytical points of view and, even with the limited number of participants, there are clear testimonial analogies. Addressing the limitations of his experimental model, Delalande acknowledges the lack of a systematic approach to the analysis and that the number of participants was insufficient to draw statistical conclusions (25). However, in defense of his method, Delalande states that a scientific approach, aimed at collecting simpler responses via such methods as questionnaires, adjective grids or segmentation tasks, would deprive the results of the "richest information which permits a detailed description of listening behaviour" (26). In another comment, Delalande describes verbal testimonies as "more or less a faithful account of what happened during listening" albeit affected by the "self-image of the listener" (25).

During the latter half of the 1990s, the composer Andra McCartney conducted a program of listener-response studies using Hildegard Westerkamp's works of soundscape music (McCartney 1999). In this research the participants were asked to listen to a soundscape piece and later respond to questions about it in survey format. Although this study offers intriguing insights, its exclusive focus on soundscape music renders the research outcomes highly style-specific. McCartney analyzes the results of the study based on her "open interpretation" of the listener responses; the composer expresses that this decision was influenced by her desire to maintain an interpretational diversity (198).

The Intention Reception Project, conducted by Leigh Landy and Rob Weale, investigates how the intentions of a composer relate to the listening experience in electronic music. The goal of this research is described as gauging accessibility and appreciation in electronic music (Landy 2007: 44). For the experimental component of this study, researchers first directed questionnaires to the composers whose pieces would be used in the listening experiments. The ensuing experiments, which were conducted with listeners, consisted of two questionnaires and three rounds of listening. Before each round, the information provided to the listener regarding the piece was gradually increased. During all three listening sessions, participants reported their immediate responses to the music in the form of thoughts, images and ideas that come to mind, via a real-time written questionnaire. A separate questionnaire with questions on the listening experience was filled exclusively after the first round. The experiments were conducted strictly with fixed stereo pieces that include "real-world sounds that are identifiable" (44). These studies revealed that when inexperienced listeners are provided with dramaturgical information regarding a piece, they are able to use this information to guide themselves through parts of the music that are problematic in terms of access and appreciation (Weale 2006: 196).

With an online survey conducted with 21 participants in November 2010, the composer Adam Basanta examined "the language of listener responses to electroacoustic music" (Basanta 2013). As listening material, short excerpts of music consisting of real-world field recordings and synthetic pitched materials were composed. Each participant was instructed to listen to an excerpt and provide affective, imaginal and other kinds of responses in written format. Responses relating to "positioning of the listening-self", the "place image" of the piece, and cultural-ecological references were found to be common across all participants with varying experiences with electronic music.

Building upon Landy and Weale's project discussed earlier, the composer Andrew Hill used "empirical data collection" (2013: 43) to investigate audience reactions to "electroacoustic audiovisual music". During various phases of this study, audience members were asked to respond to qualitative questionnaires, developed in the light of those from the Intention Reception Project (45). These questionnaires were intended to collect information regarding the material properties of an audiovisual work, semantic and emotional responses of the audience to this work, and whether the audience members wanted to keep experiencing the piece or obtain contextual information about it (45), the latter of which was found to "narrow the interpretative potential of the work" (43).

Experiment Design

The modality of feedback in the current experiment is written language. Usage of verbal feedback is a prevalent method in studies on auditory perception. Furthermore, experimental evidence suggests that there is a substantial overlap between the neural networks dealing with verbal and non-verbal semantic information (Cummings et al. 2006: 92). Another experiment-based study conducted by Orgs et al. also reveals similarities in the conceptual processing of verbal and non-verbal stimuli (2006: 267). Various other studies on environmental sounds have demonstrated the facilitatory effect of such sounds on the retrieval of semantically related words (Ballas 1993; Van Petten and Rheinfelder 1995; Gygi et al. 2007; Guastavino 2007; Özcan 2008), in support of the strong conceptual relationship between sounds and spoken words.

To maintain the richness of a music-listening experience, while at the same time harnessing the statistical potential of a free association task, I designed a two-stage model for the experiment discussed here. Although parts of my design might coincide with those from other studies, the particular combination of its sections amount to a unique methodology which is capable of capturing a comprehensive report of the listening experience. As I will shortly discuss in detail, a general-impressions task allows the participants to listen to a complete piece of electronic music without interruptions or the burden of a task. This is intended to keep the impact of experiment bias on the listening experience to a minimum. Once the listening is completed, the participants report their general impressions in free written form followed by a second listening to the piece, during which they perform a real-time free association task via custom software. While the general-impressions task also yields descriptors pertaining to cognitive processes during listening, the real-time descriptor section mines a more precise and in-the-moment collection of descriptors. To alleviate the effect of self-image described by Delalande, the experiments were conducted with a large group of participants of varying backgrounds in terms of age, nationality and engagement with electronic music.

Working with complete works of electronic music was another decision made to improve the authenticity of the listening experience. Although experimental studies using sound chunks instead of complete pieces are effective for investigating isolated parameters, this approach compromises the natural dynamics of the listening experience. Indeed, my intention with using complete works was to allow the communication between the composer and the listener to transpire at its natural scale.

Another common practice in experimental studies on electronic music is the upfront prescription of a task to be performed either during or immediately after the act of listening. In the former case, where the participants are asked to take notes while a piece of music is being played, the regular music listening experience is clearly altered. Although this method can prove effective with pieces custom-designed to gauge a certain phenomenon, it nevertheless demands that the participant is repeatedly disconnected from the act of listening. In the latter model, in which a task is described prior to hearing the piece for an ensuing survey, the listening experience remains uninterrupted. However, this model too demands that the listener assume a certain stance towards the piece. I should note that such a stance, or bias, can never be fully extracted from experimental studies, owing to the participants' awareness of the simple fact that they are being subjected to an experiment. However, assigning the participant with a distinct task prior to any music playback will inevitably encourage the participant to consciously labor towards fulfilling this task as the piece plays, which again implies a notable alteration of the listening experience. It is possible that the participant might do the same regardless of whether a task is prescribed in advance. To prevent the listeners from speculating on a task and laboring towards it, necessary instructions regarding the nature of the experiment should be given prior to listening.

Dealing with Experiment Bias

The matter of experiment bias can be viewed from two angles based on either the experimenter's or the participant's point of view. From the former perspective, an *experimenter (or observer) expectancy effect* (Zoble and Lehman 1969: 357) requires consideration. This effect occurs when the experimenter unconsciously primes the participant with instructions in a way that will encourage responses that support the hypothesis. A certain degree of expectancy effect is inevitable with verbal instructions, simply because these are intended to communicate a task to be performed by the participant in a specific modality. One way to handle this is to maintain a uniform level of bias across the separate instances of the experiment. It is therefore important that the instructions for the participants remain consistent across different instances of the experiment. To achieve this, the experiment design needs to incorporate an instruction routine and the experimenter must be proficient with the delivery of this routine. Another method to reduce observer-expectancy effect is to abstract the experimenter from the general procedure as much as possible. Since double-blinding was not applicable to the current study (for practical and methodological reasons), I attempted to reduce possible expectancy effects by designing the experiment so that I merely act as an instructor who does not take part in the sections in which the participants actively perform a task.

Another possible bias can be caused by the *demand characteristics* of an experiment (Thomas 2010). For instance, prior knowledge about the experiment might motivate the participant to satisfy (or evade) in their responses a hypothesis which they have elaborated through this prior knowledge. The adoption of a between-subject model, in which the experiment is conducted once with each participant, eliminates this risk for the current study to a certain extent. This however does not imply an inherent flaw in within-subject models, where a participant performs a task multiple times. The choice between these two approaches is determined by the aim of the experiment; the practicalities of each model are factored in accordingly in the analyses. Another measure taken to avoid the effects of demand characteristics in the current study was to request the subjects who had completed their tasks to refrain from discussing the experiment with prospective participants in cases where such an interaction was deemed a possibility (e.g. when the experiment is performed at a school).

Preliminary Study

I started designing the model and the medium of the experiment in February 2010. After an extended period of research and development, I have conducted an initial round of experiments with 12 participants between October 2011 and February 2012. The listening material for these experiments was an early version of my piece *Birdfish*. The preliminary results I obtained from these experiments were published in an article titled *A Cognitive Approach to Electronic Music: Theoretical and Experiment-based Perspectives* (Çamcı 2012). Moreover, these first 12 instances of the experiment helped delineate necessary improvements to the initial experiment design. The modifications I implemented for the next round of experiments ranged from interface refinements to broadening of the collected data.

For instance, a minor interface modification was the removal of the volume adjuster available in the initial design. This user interface element, although intended to recreate the experience of a common audio player, was never used by the participants. Other minor refinements were similarly informed by participant behavior: one of my intentions with the earlier design was to extract general categories for musical backgrounds based on the relevant information written during the general-impressions task and later use these categories in a drop-down menu in the software interface. Even with the relatively small sample group of 12 people, the musical backgrounds, which the participants identified themselves with, varied too greatly to inform a practically viable categorization. Therefore, for the next round of experiments, I added a relevant text field in the participant information form, which gave the participants the freedom to type musical background descriptors.

I also modified to the code which executed the data collection. In the first version, only the descriptor submission times were being recorded. In the final version, I implemented an event-listener which tracked the position in time when a participant started typing a descriptor. This made it possible to observe with higher accuracy the exact time in the piece when a particular descriptor would emerge. More importantly, this implementation provided information regarding the time a participant spent between starting to type a descriptor and submitting it, which allowed for meaningful interpolations in several cases and provided data for typing proficiency analysis.

The methods used to evaluate the results of the preliminary study informed the analysis of the study discussed here. Although the latter benefits from a much more extended analysis, descriptor categories extracted from the preliminary study served as a basis for the categorization of the descriptors from the current study. Furthermore, the data visualization tools I had developed for the preliminary study constituted a substantial framework for the design of the two visualization methods used in the current study.

Experiment Aim

As described earlier, the experiment contains two stages. The first stage, namely the general-impressions task, is aimed at extracting an overall report on the participant's experience of a complete piece of electronic music. This section allows the participants to evaluate the piece holistically and provide their impressions in free form. Having listened to the piece with no prior assignments, the participants are expected to rely on their overall experience in order to complete this task.

The second stage, namely the real-time input task, collects the momentary impressions and mental images that are activated in the listeners' minds as they listen to the piece. This stage is aimed at collecting gesture-level descriptors that pertain to perceptual, cognitive and affective processes. While the first stage allows for an uninterrupted listening experience, the second stage allows for a continuous and immediate reporting of the mental associations evoked by the piece. Furthermore, tracking the momentary impressions of a participant allows me to pinpoint the moments at which the descriptors have been submitted. This way I can later evaluate the gestures and the real-time descriptors that correspond to each other on the timeline of the piece.

It is expected that the two stages of the experiment complement each other with overlaps in a participant's feedback from each stage. The conjunct aim of these two stages is to extract both contextualized and in-the-moment concepts activated in the participant's mind when listening to a certain piece, and to later identify the cognitive characteristics of each piece in the form of mental categories based on the real-time descriptors.

Stimuli

Five complete pieces of electronic music were used in the experiments. Four of these were my works, namely *Birdfish*, *Element Yon*, *Christmas 2013*, and *Diegese*. The fifth piece was Curtis Roads' 2009 piece *Touche pas*. An in-depth report on the materials, tools, and conceptual intents involved in the composition of my works, as well as Roads' program notes for *Touche pas*, were provided in the previous section. The sound files used during the experiments were in 44100 Hz, 16-bit WAV format.

Dealing with both the creation and the analysis of the subject matter is one of the differentiating traits of my approach, and of artistic research in general. The said four works were created during the four years of my research conducted at a doctoral capacity. As outlined in the previous chapter, these works are composed using a variety of materials and techniques afforded by the modern electronic medium. On a conceptual level, these compositions also utilized the underlying theoretical constructs of this research, such as *gesture* and *diegesis*. In that respect, my compositional intents with each piece, as detailed in the first chapter, also suggest an experiential variety. The pieces composed prior to these four works helped me develop my hypotheses on both artistic and scholarly trajectories, which eventually merged.

My authorship of these works grants me advantages in exploring the concept to percept associations, and communicating the results of such investigations to the reader. Using the results of this experiment, I was able to delegate the cognitive evaluation of these works. Based on these external reports, I will reverse engineer my own works in the coming chapters to bind the experiment results with the hypotheses underlying these works. After three years of experimentation, I feel relatively impartial towards the analyses of my works. Furthermore, I believe that the novelty of the insights I am able to draw as the composer of these pieces outweighs the noise my involvement with this material might introduce into the data. Nevertheless, to diminish the impact of a confirmation bias this involvement may impose on the data, the categorization of the descriptors was peer-reviewed.

I used Roads' piece *Touche pas* for two reasons. Firstly, I wanted to include an external work in this study so that I would have a reference when analyzing the data on my own works. In that respect, any piece of electronic music that does not belong to me could serve this function. But secondly, one of my intents with the piece *Diegese* was to explore the concept of "music as a diegetic actor", which I will further explicate in Chapter 5. In this piece, I quote a texture from *Touche pas* by utilizing an algorithmic granulation. Using both pieces in the experiments allowed me to highlight certain cognitive characteristics pertaining to this specific gesture, and granular synthesis in general.

Participants

60 participants from 13 different nationalities took part in the experiment between May 2012 and July 2014. 23 of the participants were female while 37 were male. The average age of the participants was 28.78. Ages ranged from 21 to 61. The pool of participants included professional musicians, music hobbyists, composers, and students of sound engineering, sonic arts and sonology, as well as 22 out of the 60 participants who described themselves as having no musical background. Based on the timing data obtained from the exercise section, all participants proved to be capable of typing 5-letter words in less than 1.5 seconds indicating a typing speed of 40 words-per-minute or faster, which is significantly above the average number of real-time descriptors per piece (as shown in Table 2.1 in the next section),

implying that typing proficiency did not constitute a performance bottleneck for the participants.

Although all participants of the experiment described themselves as English speakers, they were told that they could respond in their native languages whenever they preferred to do so. Two participants used Turkish for both the written and the typed sections of the experiment. Two additional participants typed their real-time descriptors in Turkish despite having written their general impressions in English. A few participants typed occasional descriptors in their native languages but responded in English throughout the rest of the experiment. All of these instances were in Turkish with the exceptions of *kraai*, meaning "crow" in Dutch, and *canicas*, meaning "marbles" in Spanish. Non-English feedback from the participants was translated to English prior to analysis.

Setup

I designed the software components of the experiment in HTML, CSS, Javascript and PHP. The browser-based interface communicates with a local SQL database to store the input from the participants. The choice of the web browser as a platform, and the overall design language of the interface is intended to reduce the amount of experiment mechanics the participants would need to be acquainted with by utilizing familiar interface elements and simple modes of interaction. Labels in the software interface and the text on the participation form were written in English to cater for an international group of participants.

The listening sections were conducted with closed-back (e.g. Beyerdynamic DT-770) or semi closed-back (e.g. AKG K240) stereo headphones that were tested to be capable of reproducing the entire frequency spectrum of the works used in the experiments. To run the browser-based experiment software, either an Apple Macbook Pro laptop computer with a built-in English QWERTY keyboard, or an Apple iMac desktop computer with a peripheral English QWERTY keyboard were used. The keyboard layouts for these two devices were identical. The experiments were conducted in individual units.

Procedure

Each experiment takes 15 to 20 minutes. Experiments are conducted between subjects, meaning that each instance of the experiment is administered with a different participant. The pieces are rotated across participants to achieve a random allocation with an equal number of instances for each piece. Verbal instructions are provided prior each section. The experiment procedure involves an initial listening, a general-impressions task, a real time input exercise and a real-time input task.

Initial Listening

The participants are seated in front of the computer which displays the software interface as seen in Figure 2.1. After a brief description of the interface, the participant is told that once the play button is pressed he or she will listen to an entire piece of music without interruptions. It is explained that what the participant will hear is not a test piece, and that they will not be asked quantitative questions about it afterwards. No information regarding the piece (e.g. title, duration, composer name) is disclosed to the participant. They are asked to simply listen to it, and try to enjoy it as they would with any piece of music. The participant is then provided with stereo headphones to listen, in its complete form, to one of the five pieces of electronic music listed above.

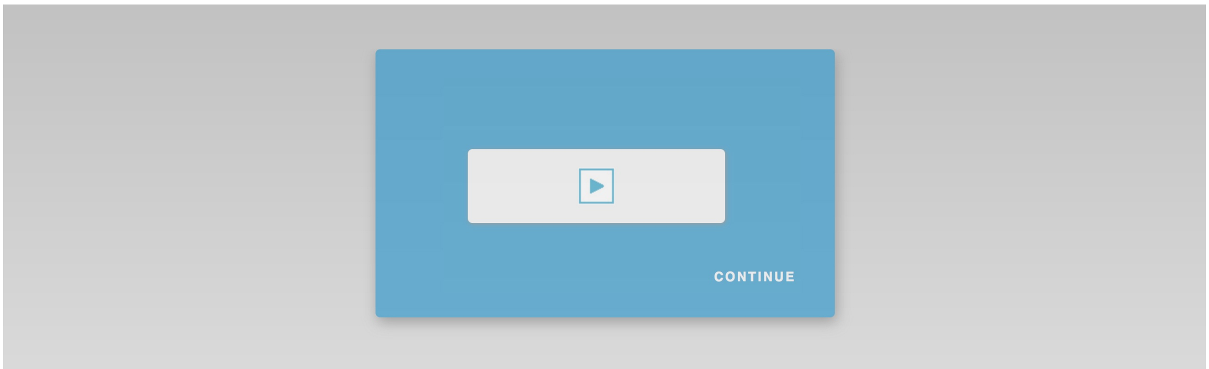


Figure 2.1: Initial-listening section software interface

General-impressions Task

When the initial round of listening is completed, the subject is asked to sign a participation form printed on A4 paper. The participant is then instructed to write, on the remainder of this paper, their general impressions as to anything they might have felt or imagined, or anything that came to their minds as they listened to the piece. This instruction was intended to cover a wide range of mental activations that could represent perceptual, cognitive and affective processes. They are advised to feel relaxed and take their time: it is explained that they could write freely in whatever form to whatever extent they prefer and no time constraints would be imposed for this section.

Once the participant indicates that they have completed the general-impressions task, they are asked to return to the computer and press the continue button on the software interface where they left off. In the following page, they are presented with a digital form, as seen in Figure 2.2, where they can input their personal details. Once this is completed, the participant proceeds to the exercise section for the second part of the experiment.

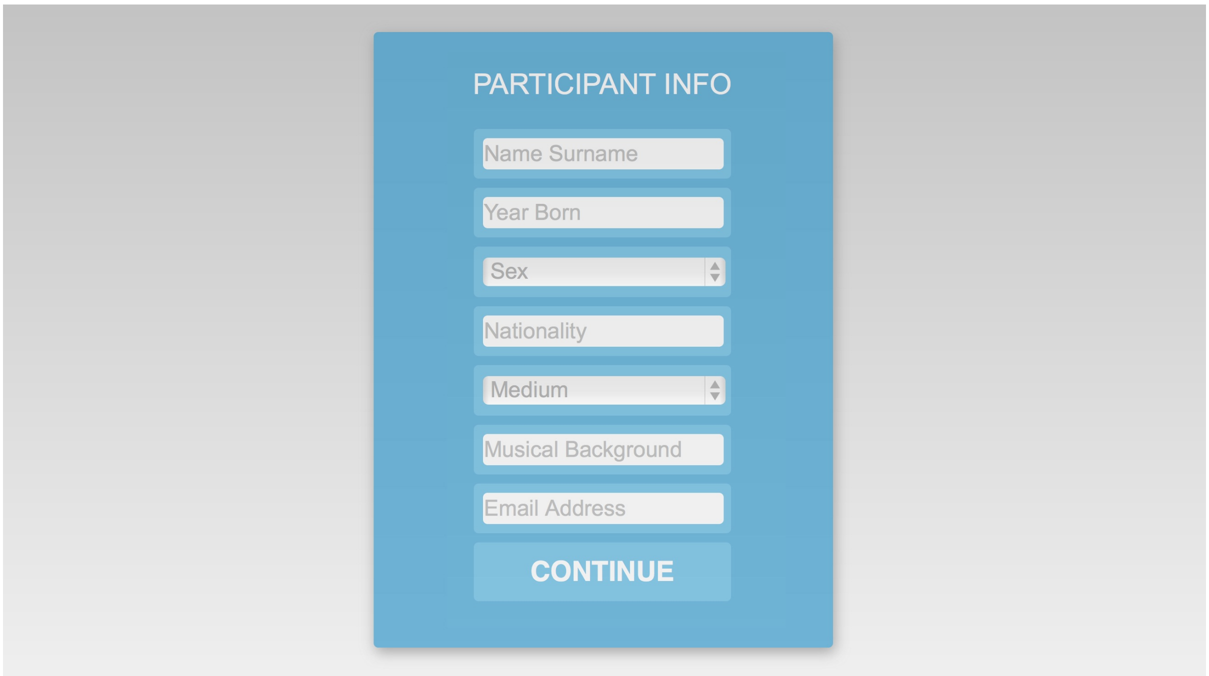


Figure 2.2: Participant information form

Real-time Input Exercise

In the exercise, the participant is greeted with the interface seen in Figure 2.3. It is explained that once the participant hits play, they will hear a voice recording of a text, and they are instructed to pick random words from this text, type them and hit the enter key to submit them one at a time. It is stated that once they press play, the cursor would flash in the text box ready for typing, and once they hit the enter key the field would be emptied and the cursor would go back to its initial position. This design ensures that the participants can secure their hands over the keyboard during the real-time input section of the experiment without having to navigate through the interface.

The main purpose of the exercise is to acquaint the participant with the software and hardware layout of the experiment medium. Both filling out the personal information form and the exercise section familiarize the participant with the input device. Although a standard QWERTY keyboard is used for all instances of the experiment, it is still necessary for the participant to practice typing with the particular keyboard used in the experiments prior to the real-time input task. The exercise section also allows me to monitor whether the experiment software is properly communicating with the SQL database. The recording used in the exercise lasts 30 seconds. However, if the participant experiences a problem during the exercise, it can be repeated. Once the exercise is completed, the participant is asked to press the continue button to proceed.

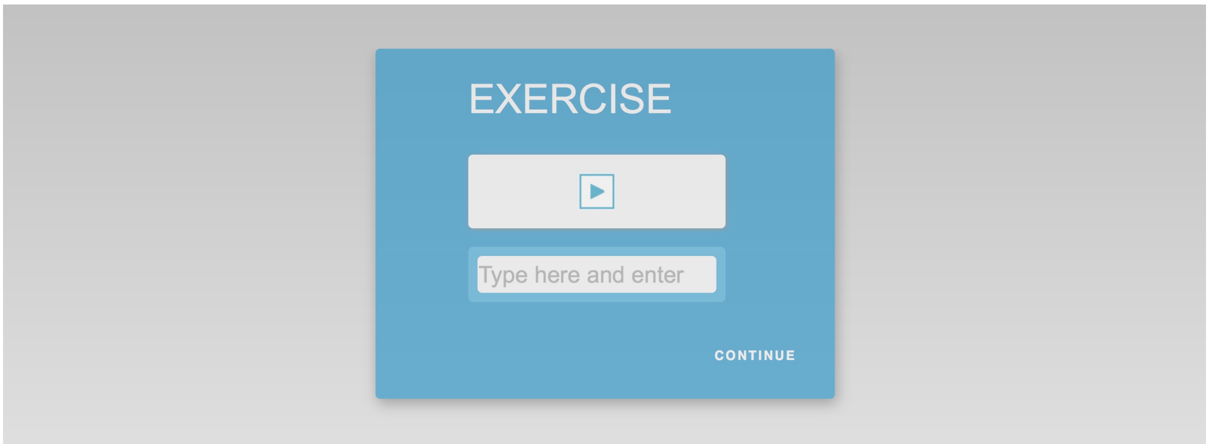


Figure 2.3: Real-time input exercise software interface

Real-time Input Task

In this section, the participants use the interface seen in Figure 2.4, which is almost identical to that from the exercise section, to complete a real-time free association task. Prior to this task, it is described to the participant that once they press the play button, the piece which they previously listened to will play a second time. It is explained that in this section, they are expected to submit descriptors as to what they might feel, imagine or think, the moment such descriptors come to their mind. The participants are advised to be relaxed and spontaneous, and not to contemplate what to type.

The interface seen in Figure 2.4, and the interaction method described in the exercise section are designed to encourage this spontaneity. Although the text box and the corresponding database structure allow for the entry of larger forms, this layout is intended to keep the participants from *disconnecting* from the listening experience for extended periods to type such entries to the detriment of the real-time nature of this section. The participants are also asked to disregard any typing errors and submit their descriptors as soon as they finish typing them.

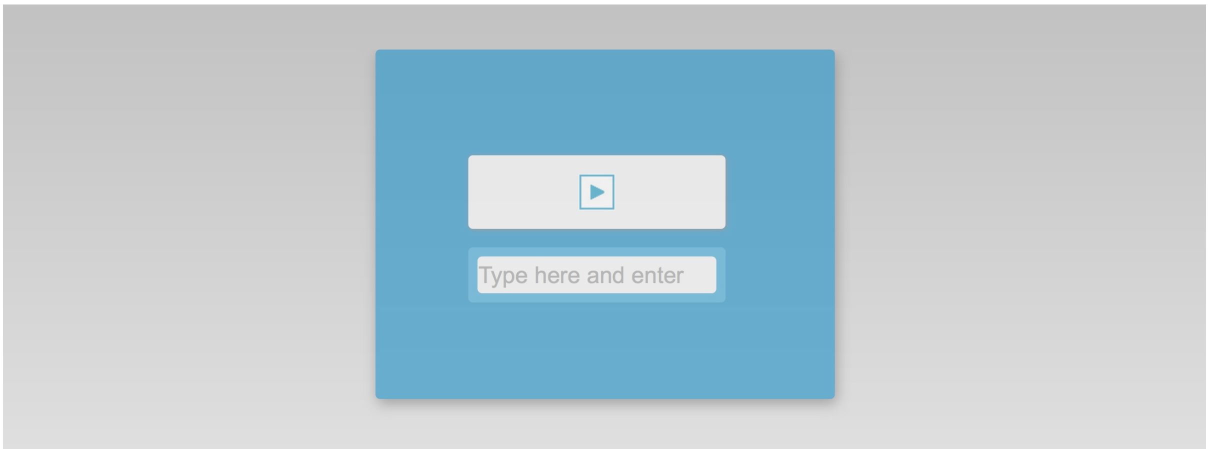


Figure 2.4: Real-time input task software interface

DATA ANALYSIS

Table 2.1 seen below provides an overview of the number of descriptors submitted in total for each piece. Although the vast majority of the descriptors were in the form of single words or two-word noun phrases, there were longer descriptors as well. The longest descriptor submitted was "trying to make the puzzle but can't quite do it" with 10 words.

The general impressions consisted of one or a combination of various forms including list of words, list of sentences, prose and drawing. Although no time constraints were specified for this section, most participants spent between 5 to 10 minutes writing their general impressions.

	Birdfish	Element Yon	Christmas 2013	Diegese	Touche pas
Piece Duration	4'40"	3'45"	2'16"	1'54"	5'30"
Total Number of RTD	334	170	198	161	339
Average Number of RTD per Participant	27.83	14.16	16.5	13.41	28.25
Average Number of RTD per Minute	6.05	3.77	7.27	7.05	5.13

Table 2.1: Total and average numbers of real-time descriptor (RTD) per piece, participant and minute

Data visualization

Experimental studies on auditory perception and cognition largely deal with *sound samples*. The statistical representations of the data in such studies are therefore sufficient to draw conclusions. However, the current experiment is conducted with complete pieces of electronic music. Therefore, the temporality of the listening experience needs to be incorporated into the analysis process. Given the sheer amount of descriptors submitted by the participants, it became apparent early on that custom tools for data visualization would be necessary for a meaningful evaluation of how the descriptors relate to the piece both within and across participants. For the comparative analysis of the real-time descriptors, I have developed two interactive visualization software using the multimedia programming language *Processing*.

Single-timeline Dynamic Visualization

The single-timeline dynamic visualization places the descriptors for one piece from all 12 participants on a musical timeline. This allows for a sequential analysis of the entries and provides a compiled overview of descriptors from multiple participants. However, given the number of real-time descriptors submitted for each piece as seen Table 2.1, it was impossible to make each descriptor readable when placed on a static timeline. To overcome this issue, I have designed a dynamic visualization software which reacts to the passage of time and highlights the relevant descriptors.

In both visualizations, the x-axis represents the timeline of the piece. In this particular visualization, all descriptors pertaining to a piece are placed on this timeline in a vertically cascading pattern as seen in Figure 2.5 with a vertical line drawn from the descriptor to its exact point on the timeline. Pressing the space bar on the keyboard starts the playback of the piece. As playback proceeds, descriptors which were submitted in the vicinity of that specific moment in the piece dynamically expand as seen in Figure 2.5. In order to maintain the temporal relevance between the piece and a given descriptor, the visual placement of each word is based on the time at which the participant started typing the descriptor. An entry begins to expand as the elapsed time approaches its point on the timeline and reaches it most extensive form when the time in the piece at which the typing of the descriptor began is reached. While this expanding behavior makes it possible to view all the descriptors on a single timeline, the fading behavior establishes a sense of context for the expanded descriptors.

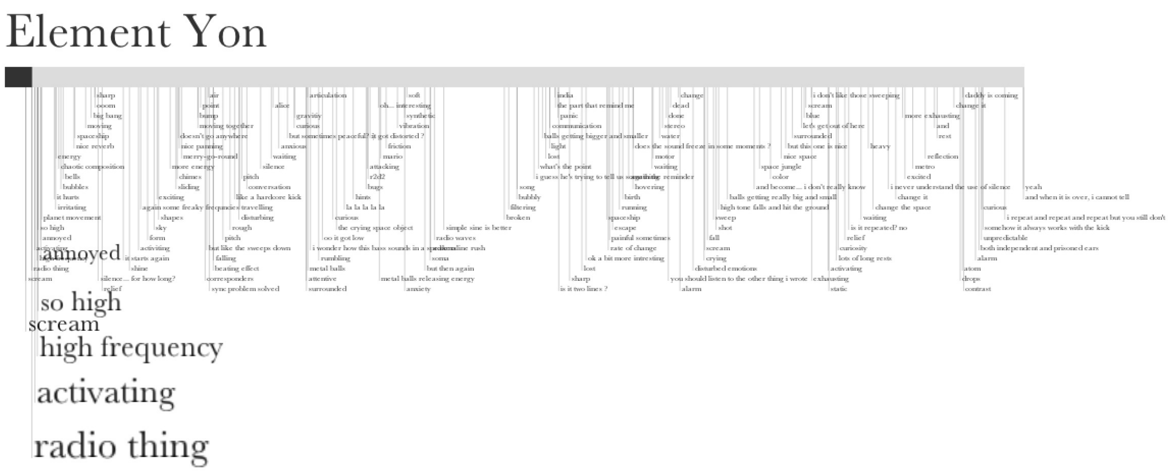


Figure 2.5: Single-timeline dynamic visualization of real-time inputs

The elapsed portion of the piece is displayed in a darker color on the timeline. Clicking on the timeline allows for jumping to different moments in the piece. The dynamic visualization also responds to these jumps by expanding the descriptors at the clicked point. The single-timeline dynamic visualization reveals the relationship between a particular gesture in the piece and the multitude of descriptors submitted by various participants at the moment the said gesture happens.

Multiple-timeline Visualization

To perform contextual analyses within and across participants, the descriptors had to be separated between different timelines. Similar to that of the single-timeline dynamic visualization, the software for multiple-timeline visualization is also capable of playing back the audio file relevant to the data which are being visualized. The visualization is static except for the progress bar as seen in Figure 2.6. It is likewise possible to jump to different points in the piece by clicking on the timeline; in this visualization however, doing so updates the progress bar for all the timelines, effectively highlighting the correspondences across participants. This visualization is also useful when performing per-participant contextual analyses of individual descriptors.

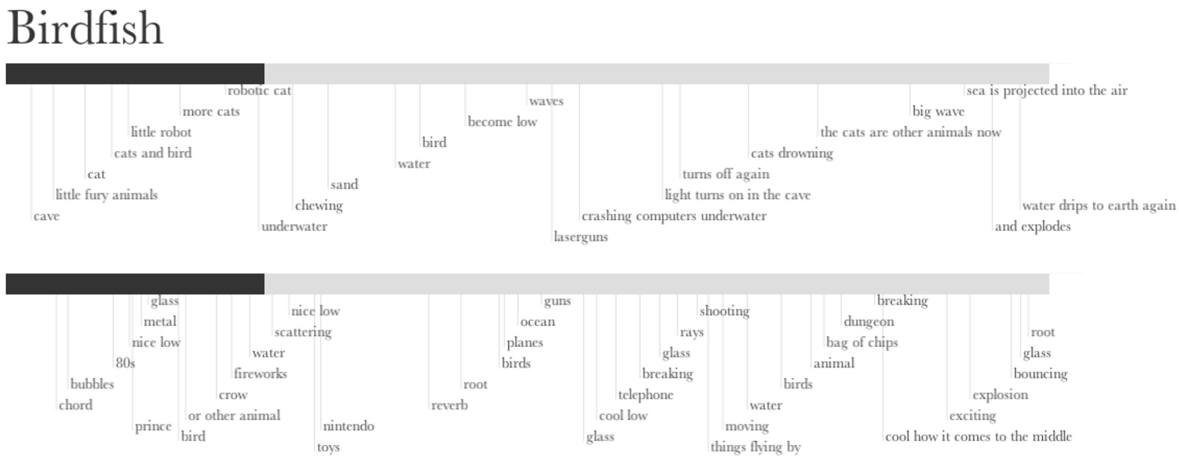


Figure 2.6: Multiple-timeline visualization of real-time inputs by two participants

Analysis Methods

Given the breadth and variety of the data obtained in the experiments, various tools and methods were employed for analysis. These included descriptor categorization, correspondence analysis, discourse analysis, and comparative analysis using the general impressions and the visualizations of the real-time descriptor data. The interpretations of these analyses will be dispersed throughout this book in support of the theoretical discourse.

Categorization of the Descriptors

In order to analyze the descriptors gathered from the real-time free association task, a categorization was imposed upon the data, following the model of many studies dealing with auditory perception (e.g. Ballas 1993; Marcell et al. 2000; Gygi et al. 2007; Guastavino 2007, Özcan 2008). In the preliminary studies an iterative process of thematic analysis was applied to the data to produce a set of descriptor categories. Once the emergent categories were determined, the category membership of each real-time input was assessed through forced-choice categorization. The categories derived from the preliminary study were *source*, *concept*, *scene*, *emotion* and *perceptual descriptors*.

To analyze the data from the current experiment, all of the 1202 real-time inputs were categorized under these five groups in an initial run. If a descriptor consisted of multiple words and noun phrases, it was split up into its constituents that would fall under a category individually (e.g. "computers underwater" broken into "computers" and "underwater"). When categorizing ambiguous descriptors, three cues were utilized: the musical background of the listener, the moment in the piece where the descriptor occurred, and the context of the descriptor (i.e. adjacent descriptors). 5 entries whose categorical correspondence could not be determined either due to obscurity (e.g. "but then again") or over-generality (e.g. "sound") have been left out of the categorization. After several iterations of the categorization process, it became apparent that some of these categories were too broad and had to be split up into subcategories. Furthermore, the addition of new categories was also found to be necessary.

Upon further evaluations of the categorical distributions, a list of labels which sufficiently represented the data set was established. This final list of categories addresses the various stages of meaning attribution such as perception, recognition and identification (Özcan 2008: 18), as well as processes of affective appraisal. The said list includes the following descriptor categories: *source descriptors* (SD – subcategorized into object descriptors, action descriptors and musical descriptors); *concept descriptors*; *location descriptors*; *affective descriptors* (AD – subcategorized into emotion descriptors, appraisal descriptors and quality descriptors); *perceptual descriptors* (PD – subcategorized into auditory descriptors and featural descriptors); *meta-descriptors*; *onomatopoeia*. The selection of the categories, and the forced-choice categorization of the descriptors were peer-reviewed by sound design specialist Dr. Elif Özcan Vieira, who is one of the advisors for the current book.

The source descriptor group covers submissions which can broadly be prefixed by the phrase "sound of". The three sub categories refer to *object source descriptors* (e.g. "water", "telephone", "frogs", "wind"), *action source descriptors* (e.g. "breathing", "explosion", "scratching", "bouncing"), and *musical source descriptors* (e.g. "guitar", "lullaby", "rhythm", "pop band"). Objects and actions can refer to both animate and inanimate beings. Musical source descriptors are objects of both animate (e.g. "Mozart) and inanimate (e.g. "percussion") nature. The choice of separating musical source descriptors from object source descriptors originated from both the significant number of relevant entries and my intent to research listener tendencies towards the usage of meta-musical forms as descriptors. This aspect will be further investigated in Chapter 5.

The concept descriptor category includes such descriptors as "waiting", "lights", "transition" and "summer". As seen in these examples, concept descriptors can be objects or actions; however, they do not refer to sounding objects/phenomena in themselves. On the other hand, these descriptors might refer to concepts that *imply* such phenomena, as in "war", "activating", "Chinese" and "science fiction".

Location descriptors refer to imagined spaces other than the one inhabited by the listener (e.g. "jungle", "underwater", "cave", "hallway"). A location descriptor can also indicate imaginary spatial attributes as in "distant", or merely imply an imagined yet unspecified environment as in "space" and "outdoors".

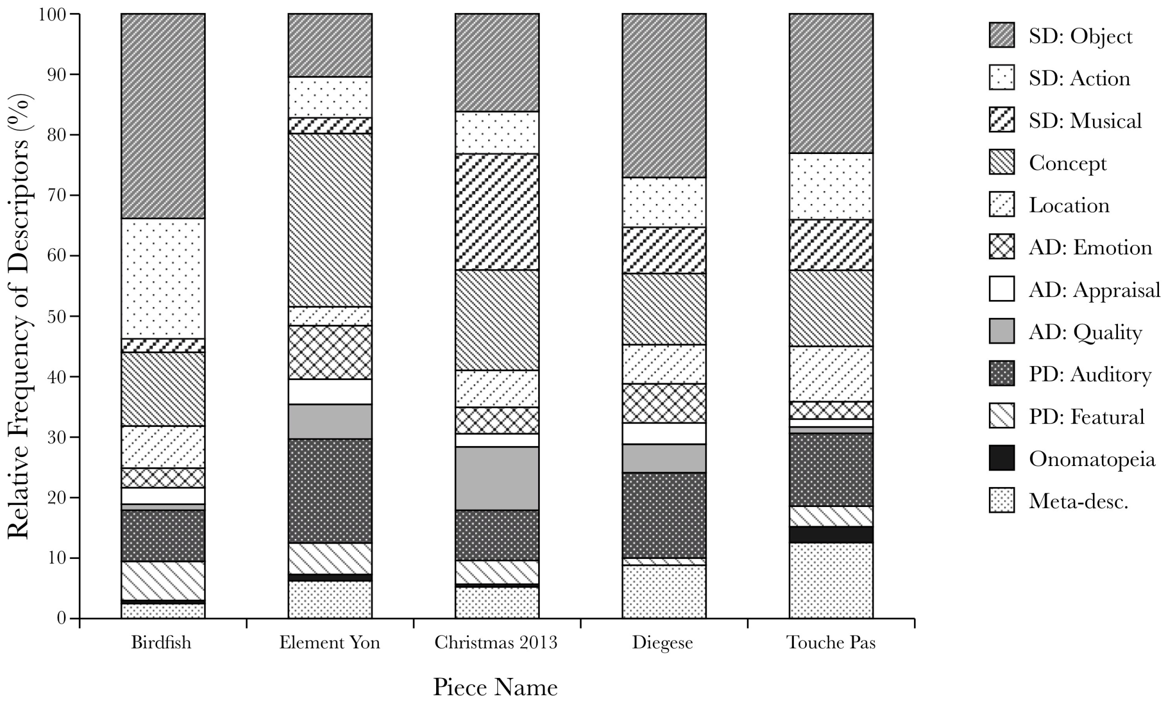
Affective descriptors are grouped into three subcategories. *Emotion descriptors* define feelings that relate to the listener's experience, such as "curious", "stress", "relief" and "fear". *Appraisal descriptors* such as "nice", "cool", "lovely" and "great" are often followed by a source descriptor as in "nice piano" or "cool low". These descriptors denote a listener's basic appraisal of certain components of the piece on a binary basis (i.e. good or bad). *Quality descriptors* such as "weird", "familiar", "exciting" and "mellow" are affective traits which the listener attributes to an external object, as in "relaxing rhythm". Therefore, the difference between emotion and quality descriptor categories is that while the former denotes a feeling of the listener, the latter describes a feeling of an object.

Perceptual descriptors are grouped into two sub categories. *Auditory descriptors* denote perceptual qualities of the sound such as "bass", "silence", "fade in" and "pan". *Featural descriptors* denote non-auditory perceptual qualities of the imagined objects, as in "wide (room)", "small (impacts)", "deep (cave)" and "dark (forest)".

Meta-descriptors refer to the material being of the piece in itself and not the experience of it (e.g. "(great) opening", "want more bass", "pause", "end"). Such descriptors can also refer to form and technique (e.g. "counterpoint", "granular", "motif", "pitch-shifter").

The onomatopoeia category included a small number of descriptors such as "boooooom", "ding" and "hummm".

Graph 2.1 reveals the frequency distribution of each category by piece. The categorical distribution for each piece is already revealing. The reader of this book is invited to listen to these works and compare the results below with their own impressions. I will use these distributions in the coming chapters to draw conclusions both within and across the pieces.



Graph 2.1: Categorical distribution of real-time descriptors by piece

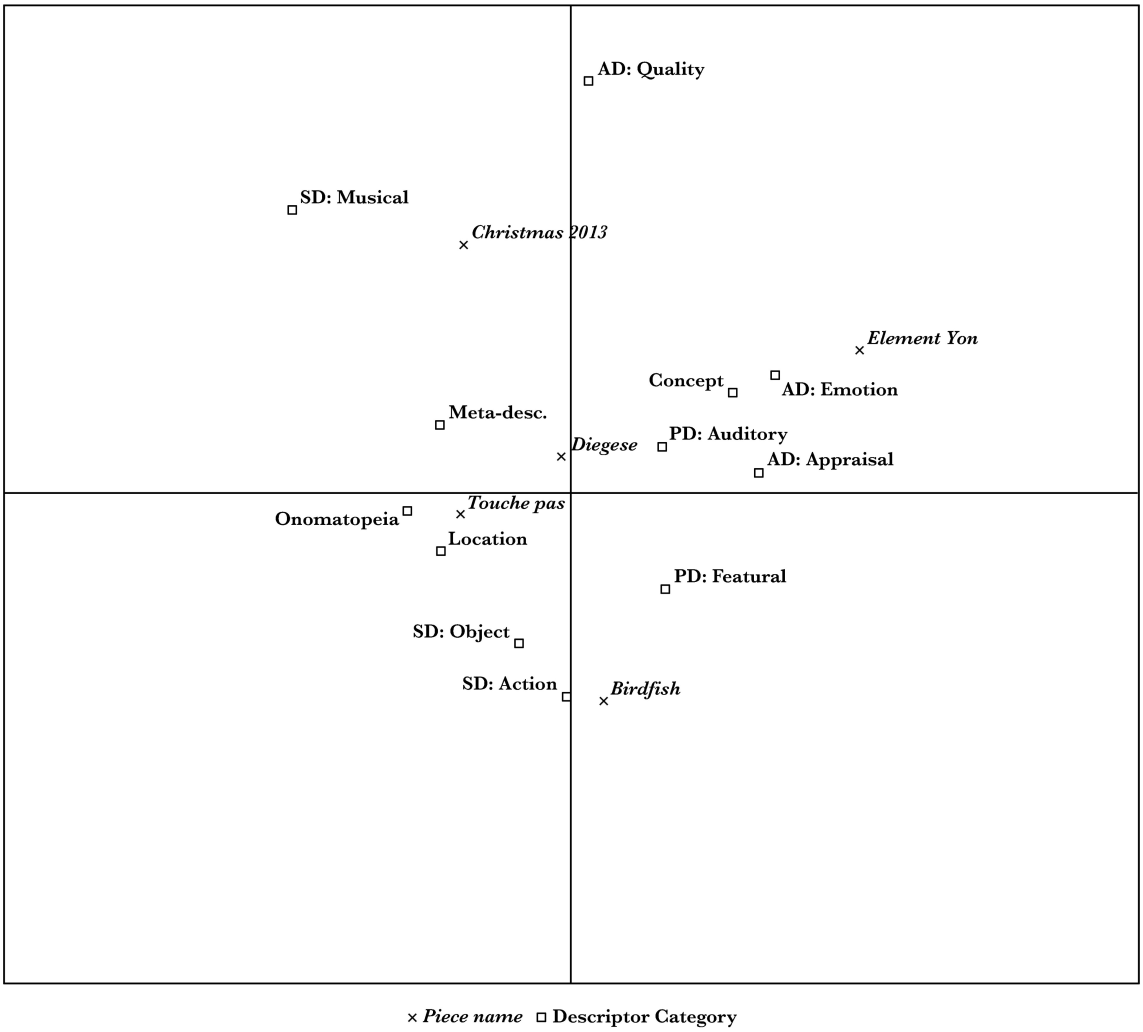
Comparative Analysis

The design of the current experiment allowed for various comparative analyses. Firstly, the general impressions and real-time descriptors were compared within participants to observe the semantic correspondence between the two sections of the experiment. Furthermore, general impressions across participants were also compared during discourse analysis as described below. For the comparative analysis of the real-time descriptors between participants I have used the custom visualization software described earlier.

The data from the two parts of the experiment displayed significant similarities within most participants. The basic themes and objects appearing in the general impressions of a participant were also apparent in his or her real-time descriptors to the most part. Therefore, the comparative analysis allowed me the use the general impressions to contextualize certain real-time descriptors in terms of the narratives and forms perceived by the listener. Conversely, it also allowed me to use the real-time descriptors to locate the parts in the piece to which certain general impressions relate.

Correspondence Analysis

Correspondence analysis is a statistical method for visualizing the relationships between the layers of a frequency distribution matrix. The rows and columns of a two-way contingency table are displayed as points in a low-dimensional space with the aim of maintaining "a global view of the data that is useful for interpretation" (Lee 1996: 65). The analysis is a representation of the categorization data as distributed on a two-dimensional graph in relation to their frequency of occurrence in each piece. The representation contextualizes pieces both within the categories and across other pieces. A correspondence analysis of the data from the current study can be seen in Graph 2.2. The five pieces used in the experiment are marked on the two-dimensional correspondence graph with an "×", while descriptor categories are marked with a "□".



Graph 2.2: Correspondence analysis between pieces and descriptor categories

Discourse Analysis

The content of the general impressions written by the participants was open to various interpretative methods thanks to its free form. One of the methods used for this purpose was discourse analysis. In this analysis, general impressions expressed in a multiplicity of formats (e.g. prose, list, drawing) are split into “meaningful sections” (Özcan 2008). For instance, the sentence “it reminded me of marbles falling” is reduced to the words “marbles” and “falling”. This way, a list of keywords that represent a reduction of general impressions are generated. These keywords, in return, are grouped across participants by semantic similarity and evaluated on the bases of their frequencies. The data on the usage of different modalities to express general impressions are also indicated below. Multiple modalities used by a single participant (e.g. both a word list and a drawing), were counted separately. The analysis of an individual general-impressions session conducted with 8 participants who listened to *Christmas 2013* can also be found below.

Real-time inputs were also analyzed for semantic similarities. For a real-time descriptor to be evaluated in the discourse analysis below, it had to be repeated by at least 3 separate participants. The number of occurrence for each word is denoted next to it within parentheses. Certain real-time descriptors displaying semantic proximity were collated under a single descriptor. The collated descriptors are also provided below in a separate list.

Birdfish

<table>
<tr><td colspan="2">General Impressions (word list (5), sentence list (4), prose (3), drawing(1))</td></tr>
<tr><td colspan="2">[water, bubble, splashing, sparkling, fluid, flow, liquid, waves, lake],
[living, creatures, animal, amphibian, bird],
[slimy, worm, snail, squishing, insect, swarm],
[alien, Zerg, Starcraft, sci-fi, star wars],
[high tech, robots, electronic],
[granulating, grinding],
[metallic, blades, gong],
[sense of space, cave, Efteling], bass, dialogue</td></tr>
<tr><td colspan="2">Real-time Descriptors (used by a minimum of 3 participants)</td></tr>
<tr><td>water (12), underwater (3), bubble (3),
bird (7), flying (4),
creature (7), cat (4),
bass (6), big (5),
laser (4), war (3), metal (3),
bug (3),
(sense of) space (3),
mouth (3),
high frequency (3), small (3)</td><td>Collated Descriptors:
water, wet, liquid, fluid, something spilling;
bug, ant, swarm;
animal, creature;
mouth, eating;
bass and low frequency;
high frequency and high pitch.</td></tr>
</table>

Element Yon

<table>
<tr><td colspan="2">General Impressions (prose (6), word list (3), sentence list (3), drawing(1))</td></tr>
<tr><td colspan="2">[wide spectrum, spectral, high frequency, low frequency, contrast],
[electronic, oscillators, synthetic, abstract],
[unpredictable, unstable, unclear, confusing, surprising, exciting],
[dangerous, scary, chaotic, argument],
[painful, irritating, exhausting, annoying], [relief, relieving, calm],
[slow movement, stable, still], silence,
[science fiction, Tron]</td></tr>
<tr><td colspan="2">Real-time Descriptors (used by a minimum of 3 participants)</td></tr>
<tr><td rowspan="2">disturbing (5),
rest (5), relief (4),
sweep (4),
conversation (3)
high (3), frequency (3),
pan (3),
static (3),
repeat (3),
(outer) space (3),
cry (3),
I (3)</td><td>Collated Descriptors:</td></tr>
<tr><td>disturbing, painful, annoyed, irritating, hurt;
rest, freeze, static, wait;
relief, release, peaceful, silence;
conversation, communication, he’s trying to tell us something;
cry, scream;
high, sharp;
frequency, tone, pitch;
sweep, slide, fall;
repeat, again;
space, spaceship;
pan, travel, move.</td></tr>
</table>

Christmas 2013

General Impressions (prose (5), sentence list (5), word list (4), drawing (1))	
[creepy, scary, thriller, paranormal activity], [nervous, stressed, anxiety], [relaxing, happy, calm, relieved, hope, fairy-tale], [melodic, piano, music, song, ballet, cliché, familiar], [space, extraterrestrial, astronomy, science, computer], water	
Real-time Descriptors *(used by a minimum of 3 participants)*	
music (10), piano (9), scary (5), machine (5), (sense of) space (4), suspense (4), storm (4), rumble (3), electronic (3), familiar (3), nice (3), bird (3)	*Collated Descriptors:* music, soundtrack, ballet, a dance, Mozart, jazz, Yes (band), Pink Floyd, Christmas song, cliché; electronic, electricity; scared, scary, Paranormal Activity (film), creepy, death; rumble, low drone; machine, robot, modem, matrix, inhumane; storm, thunder, turbulence; suspense, expectation, anticipation, waiting

Christmas 2013

Individual General-impressions Session (prose (4), sentence list (3), word list (2))
Christmas, [instruments, drums, piano, harmonium], [tonal thread, melody, cadence], [nostalgia, memory, 80s], flying, movement, slow, space

Diegese

General Impressions (sentence list (6), prose (5), drawing (2), words (1))	
[piano, keyboards, instrumental, song], [comfortable, pleasing, cool, happy], [ball, ping pong balls, spherical, circular objects], [bouncing, drop, percussive, impulse], [tiny organisms, insects], [sands, grains], [pond, liquid, water, waves, boiling, humid], [imaginary, mysterious, science fiction, Alice in Wonderland]	
Real-time Descriptors *(used by a minimum of 3 participants)*	
piano (7), insect (5), ball (5), drop (3), door (3), dense (3), exciting (3), weird (3), bass (3), panorama (3)	*Collated Descriptors:* insect, bug; pinball, ping pong ball, ball, bubble; dense, complex; weird, uncomfortable, creepy

Touche pas

<table>
<tr><td colspan="2">General Impressions (prose (6), sentence list (4), word list (3), drawing (2))</td></tr>
<tr><td colspan="2">[marble, ball, bowling ball, circular, coin],
[bouncing, dripping, falling, breaking, impact, percussion, door (knocking)],
[granular, pieces, particles],
[convincing physicality, visual],
[calm, relaxing, meditative, relief],
[silence, pauses, ending],
[water, fluid],
[distant, far away, afar], sense of space,
material, panorama, motif, fun</td></tr>
<tr><td colspan="2">Real-time Descriptors (used by a minimum of 3 participants)</td></tr>
<tr><td rowspan="2">ball (6),
again (5), repetition (4),
water (5), drop (3),
percussive (4),
(sense of) space (4),
bells (4)
reverse (4),
grain (3),</td><td>Collated Descriptors:</td></tr>
<tr><td>ball, marbles;
grain, granular;
percussive, gong, xylophone, woodblock;
reverse, rewind</td></tr>
</table>