Considering Audience's View Towards an Evaluation Methodology for Digital Musical Instruments

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ABSTRACT
The authors propose the development of a more complete Digital Music Instrument (DMI) evaluation methodology, which provides structured tools for the incremental development of prototypes based on user feedback. This paper emphasizes an important but often ignored stakeholder present in the context of musical performance: the audience. We demonstrate the practical application of an audience focused methodology through a case study ('Illusio'), discuss the obtained results and possible improvements for future works.

Keywords
Empirical methods, quantitative, usability testing and evaluation, digital musical instruments, evaluation methodology, Illusio

1. INTRODUCTION
The use of computers in the design of novel musical instruments has led to an extraordinarily rich body of work throughout its relatively brief history. Notable examples include MUSIC and Radio Baton, by Max Mathews in 1957, The Hands, by Michel Waisvisz in the 1980s, Hyperinstruments, by Tod Machover in 1986, The Buchla Lightning and others [12] [19].

In recent years, the amount of research concerning Digital Musical Instruments (DMIs) has increased dramatically, as illustrated by [13] and [14]. DMIs can be defined as a music-making system which consists of a separate control interface and sound generator connected via a mapping strategy [11]. While acoustic musical instruments are limited by their physical means of sound-production, this separation (referred to as 'control dislocation' [13]) allows DMI designers to explore the process of interaction with more freedom.

The growing interest in DMIs has prompted a large number of questions that are still open. One of the most relevant is: how can these systems be objectively evaluated?

The importance of this question becomes clear when we observe the nature of DMI development – experimentation and ongoing development of prototypes are integral parts of the process.

As mentioned by Wood [20], a critical ingredient for designing systems that are well-suited to their goal is "understanding potential users". Focused observation techniques and detailed analysis of the resulting data are essential characteristics of any good development process. Structured evaluation methods can increase the efficiency of user feedback and provide better tools for its analysis. Despite its importance, research about the issue is sparse [18].

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Table 1. Analyzing NIME conference publications from 2009, to 2011 based on a similar study made by Stowell et al.[18]

Evaluation Type	NIME Conference year		
	2009	2010	2011
Not applicable	15	25	12
None	20	20	10
Informal	7	7	2
Formal quant.	5	4	6
Formal qualit.	3	5	3
Total formal	8 (22%)	9 (25%)	9 (42%)

Taking into account the proceedings of the International Conference on New Interfaces for Music Expression (NIME) of the last 3 years, despite perceiving a percentage increase in the last year, the number of papers employing formal evaluation methodologies is still low. The lack of any standard approaches of evaluation makes it difficult to compare results.

One aspect that must be considered in an evaluation process is the variety of stakeholders involved in the use, conception, perception and even commercialization of a musical device.

As mentioned by O'Modhrain in [14], this leads us to a more generic concept of evaluation, where the whole process should consider:

- Performer's view - How effective is the relationship between performer and device? Does it allow the performer to reach all of his musical intentions?
- Audience's view - Is the relationship between performer and device established in such a way that those observing the performance might be affected sensitively?
- Manufacturer's view - How effective is the system from a commercial perspective?

An initial step towards a structured DMI evaluation methodology examined the performer's view [2]. Our current research aims to develop further this methodology by focusing upon the audience's view. In doing so, we expect both perspectives to complement each other and, therefore, permit a more thorough investigation into DMI evaluation.

2. AUDIENCE'S VIEW

The phenomenon of control dislocation has undoubtedly introduced, even within a century which has seen “the great opening-up of music to all sounds” [22], one of the greatest challenges to the ideological boundaries of music in history [17]. The rapid advance of digital technology over the last 30 years has allowed musicians to transgress the boundaries of physical cause-and-effect, at least from the observers’ perspective, and adopt the computer as the “interpreter between our physical body and the sound production" [17].

It has been perspicaciously observed that we cannot simply transplant our understanding of spectatorship from the domain of acoustic musicianship to that of digitally-mediated performance [9]. Accordingly the creation of meaningful and perceivable connections between human action and sound has been identified as a key point for making a performance convincing for the audience [14]. The ability to evaluate the extent to which an audience can understand these connections would prove a valuable asset to DMI designers.

According to Davis [4], a performance ecosystem comprises four parts: the instrument – an artifact that is manipulated to produce music; the performer – an agent who directly interacts with the instrument; the listener (referred-to here as ‘the audience’) - who watches the interaction and has an indirect relationship with the instrument; and the environment – the place where the performance takes place.

In traditional human-computer interaction (HCI) design, there is no equivalent to the audience as defined above. HCI design models focus almost exclusively upon the direct user of the system. In DMI research, this has led to a predominance of performer-centered design and an insufficient treatment of the audience.

An early approach by Hsu et al. [10] evaluates DMIs based on both performer and audience perspectives. A quantitative experiment was performed, with questionnaires applied in loco, in order to rate the experience of both parties during performance. It is important to note that the questionnaires took into consideration the audience’s subjective, artistic judgment of the music performed, based on their previous experience of similar pieces. This brought variables to the evaluation process that did not concern the instrument itself – such as the skills of the performer and the artistic quality of the music.

The most comprehensive research regarding the audience's view of DMIs has been conducted by Fyans, Gurevich and Stapleton [8] [9] [6]. Their experiments were constructed according to a set of interaction design guidelines (developed by Bellotti et al [3]) that focus upon the communicative aspects of interaction. This approach, which was inspired by analysis of human-human communication directing the design of systems, was inserted in the context of communication between a performer and the audience, mediated by DMIs. It is based on five questions:

- Address (hereafter called Cause comprehension) - "How does the spectator know that the performer is in direct communication with the system?" - concerns the audience's understanding of which input actions are possible to the user;
- Attention (hereafter called Effect comprehension) - "How does the spectator know that the system is responding to the performer?" – concerns the audience's understanding of which output the system is generating;
- Action (hereafter called Mapping comprehension) - "How does the spectator think the user controls the system?" - concerns the audience's understanding of how the mapping between input actions (cause) and output results (effect) functions;
- Alignment (hereafter called Intention comprehension) - "How does the spectator know that the system is doing the right thing?" - concerns the audience's understanding of the intentions of the performer;
- Accident (hereafter called Error comprehension) - "How does the spectator know when a mistake occurs?" - concerns the audience's understanding of mistakes made by the user and the system.

Fyans et al. focused exclusively upon two of these questions (Intention and Error) to build a model of audience's error-comprehension based on the concept of mental models [6]. This model was subsequently used for conducting qualitative experiments [8].

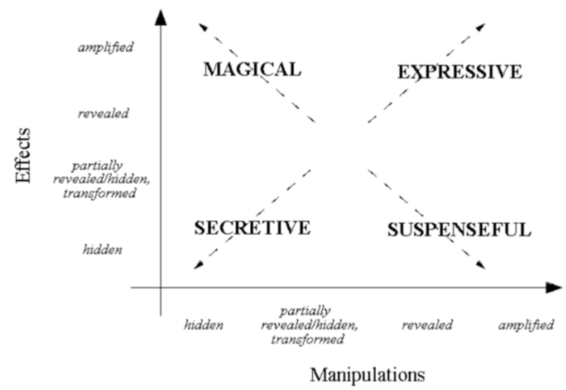


Figure 1. Reeves et al. [16] taxonomy for classifying musical interactions according to audience's view

A markedly different approach to the issue of DMIs and audience perception was adopted by Reeves et al. [16]. Their method classifies musical interactions according to the audience’s perception of the relationship between input manipulations and audio output (Figure 1). Interactions are classified according to four categories – hidden, partially revealing, transforming and amplified – defined as follows:

- Secretive - Represents when interaction tends towards hiding to the audience both performer's input manipulations and the instrument's output effects;
- Suspenseful - Represents when interaction tends towards revealing to the audience the performer's input manipulations but hiding the instrument's output effects;
- Magical - Represents when interaction tends towards hiding to the audience the performer's input manipulations but revealing the instrument's output effects;
- Expressive - Represents when interaction tends towards revealing both performer's input manipulations and the instrument's output effects.

Besides providing design guidelines for reaching each one of these categories, this work is also important as a pioneering attempt to analyze how the audience perceives new musical interfaces.

3. SCOPING

Before introducing our methodology proposal, it is essential to untangle some concepts from previous works in order to provide a clearer view of the context.

The process of perceiving a musical performance is a complex phenomenon that is intrinsically linked to social, cultural, technical, perceptual and emotional relationships [9]. This implies several different possible approaches.

Due to scoping reasons, we decided to focus the present work on the audience's understanding of how a DMI works - as well as the kind of interaction it employs - since: (a) it engages with communicative and cognitive issues, which are understood to be sensitive in this context [9]; (b) we believe that it can be objectively measured, as suggested by previous attempts [6].

After defining the study focus, we needed to select which variables were most important to consider regarding the stakeholders involved in performance ecosystem.

- About the performer: we decided that the skill of the performer using the system is not important for the audience to understand the functioning of the DMI and omitted this concern from the study. We reasoned that the most important here was the performer desire of using the instrument as a tool for expressing his musical intentions - no matter if this attempt is successful (what should have led to a correct understanding by the audience) or not (what should have led to a sensation that the performer has made a mistake). Additional information can be found in previous works [7];
- About the artistic result: unlike the Hsu and Sosnick approach [10], we assumed that judgments about artistic quality of the performance deals with subjective aspects (e.g. taste) that exceed the understanding of how the DMI works and was not considered in the present study. However, we admit that analyzing the perceived artistic result could have given different insights that could be useful for instrument improvement. Additional information can be found in previous works [15][5];
- About the audience: the personal background (cultural, social, emotional) of each audience member may also affect our focus. We are trying to consider this aspect in the present work by using the concept of the target audience, used in others areas as advertising, product design and game design [1]. Another sensitive variable regarding the audience is its previous knowledge about what the performer is about to perform, as it can directly influence the comprehension about how the DMI works [8]. We decided to focus only on participants with no previous knowledge about the functionality of the DMI, nor previous information about the performer's intention.

It is important to highlight that this work does not attempt to judge the 'best' available instruments today. Rather, we have focused upon developing a structured methodology for DMI analysis and comparison that will enable users to assess the suitability of a DMI for a given performance context. In this way, we assure that the research can be of benefit in a wide variety of circumstances – whether evaluating the suitability of different instruments for a particular performance (e.g. selecting an interface for an art installation aimed at children) or choosing between different prototypes of the same instrument (e.g. "this version had these improvements compared with the older one").

4. EVALUATION METHOD PROPOSAL

Drawing from previously described attempts, this work proposes a synthesis of techniques that provide a more robust evaluation of the audience's understanding of how a DMI works.

This proposal consists of three steps: audience profiling, data collection and data visualization. The techniques, involved in each step, are described as follows.

4.1. Audience Profiling

This first step collects information about candidates participating in the experiment and compares it to the target audience profile of the instrument. With this, the most suitable candidates are selected.

A questionnaire approach was chosen for this process due to the easily measurable data produced. Questions cover personal topics such as their relationship with technology and music, their age, and whether they play a musical instrument. Besides these suggestions, we encourage more detailed questions to be created according to the specificity of the target audience profile.

4.2. Data collection

The second step has the purpose of collecting data from the target audience about their comprehension of how the DMI works.

We adopt Fyans et al. approach in which a performance using the DMI is recorded and the video is exhibited to the audience. However, instead of structured interviews, a questionnaire is presented to each viewer after the video. The questions are based on the human-human communication aspects presented by Fyans et al. and Bellotti et al., as follows:

- Cause comprehension - "Which part of the performer's body (or yet, which technological device) was used to interact with the system?"; "How understandable are the actions made by the user for interacting with the system?";
- Effect comprehension - "Did the system provide enough audiovisual information for the audience to understand what is happening between the user and it?";
- Mapping comprehension - "How clear is the relationship between the user's actions and the resulting sound?";
- Intention comprehension - "How successful was the user to express himself using the system?"; "Was the user's intention well understood?";
- Error comprehension - "Were the system's errors perceived (e.g. technical problems and software bugs)?"; "Were the user's errors noticeable?".

The other part of the questionnaire focuses on the relationships between the cause and the effects of the instrument and aims to classify the type of interaction provided by the instrument according the taxonomy developed by Reeves et al. Although it does not concern the understanding of how the DMI works itself, we believe that Reeves' scale could be useful for researchers as a categorization tool by pointing out a context the DMI can be inserted.

This classification is based on the results of two questions: (a) "how would the participant classify the performer's actions for the functioning of the system?", (b) "how would the participant classify the system's response to the user's actions?".

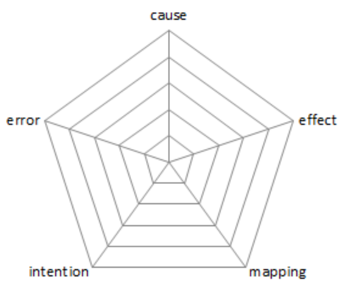
It is important to highlight the difference between perceived understanding and actual understanding: while the former concerns what people think they understand about a given subject, the second concerns what they actually comprehend – subjects are often inaccurate in estimating their real levels of understanding and usually consider themselves above-average [21].

To solve this problem, we propose the use of open questions in support of the scale-based answers and allow participants to write their own answer. Thus, it is possible to verify whether the participant properly understands how the system works - in others words, the accuracy of the answers - by examining the congruence between the users' responses and the manner in which the DMI actually functions.

We elected to use online questionnaires and online videos of performances. A local approach would have difficulties concerning the schedules of the participants, the place and it would add a more time-consuming step to the research. On the other hand, the online format of the study allowed us to reach a larger number of people that could answer the questions asynchronously from other participants.

4.3. Data visualization

The last step of our process aims to show the information in a clear and intuitive manner, helping us to visualize and analyze the results.



Interaction model: --

Figure 2. Example of an empty DMI datasheet

In order to do this, we used a datasheet consisting of a radar chart that plots the level of audience comprehension concerning the DMI (Figure 2). A brief description of the DMI is also included along with its classification and features. The chart is based upon a numerical average - ranging from 0 to 1 - of the results of the questionnaire, with each axis regarding Bellotti's communication aspects [3].

5. THE PROTOTYPE

In order to validate and refine the proposed evaluation methodology we developed a prototype - hereafter called Illusio - and performed some case studies, as described in the following sections.

Figure 3. The Illusio interface

It is important to highlight that the intention of this paper is not to defend the quality of this particular application, but instead to explain the process by means of this example.

The system Illusio - shown in Figure 3 - is a DMI that allows collaborative control of real-time recorded loops through relationships between sketches and sounds. It combines a multi-touch interface with the interaction metaphor of guitar pedals using a multi-touch surface and a "guitar pedal" (a modified old computer keyboard). Developed in Processing [1], openframeworks [2]and Open Sound Control [3], Illusio was created initially for experienced musicians, focusing on providing a one-man-band interaction in the context of music performances.

At first, the system shows a white screen in the multi-touch surface, where users can only draw rough sketches. Once completed, these sketches can be edited, grouped, removed and associated with real time recorded sounds - loops, recorded with one or more instruments via the pedals audio input.

Figure 4. User interacting with illusio

Once loops are recorded and associated to sketches, they can be manipulated (played, stopped and processed) in real-time via the multi-touch surface.

The system is shown in use above (Figure 4), and a demonstrative video is also available online [4].

6. EXPERIMENT

Regarding the audience profiling stage, 80 participants were contacted by e-mail and were asked to answer a profile test. Among them, 47 were selected due to their accordance with the target profile: people with close relation to technology and music (scored 3, 4 or 5 in a 1 to 5 scale) and who play a musical instrument.

In the data collection step, the selected participants were then contacted by e-mail, asked to watch a video from a performance with the prototype and to answer an online questionnaire as presented in the previous section.

6.1. Cause Comprehension Degree

Concerning the questions related to the cause comprehension degree, it can be seen that the majority of the participants considered they understood the user's actions, where 46% marked 4 and 35% marked 5 in a scale from 1 to 5 (where 1 is "Did not understand" and 5 is "Completely understood").

Besides, taking into account a list of body parts and also a list of interaction devices in the questionnaire, the majority indicated the actual body parts and devices used during the performance, indicating a match between perceived and actual understanding. The calculated average value related to this axis was 3,83 in a scale from 0 to 5.

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[1] http://processing.org
[2] http://openframeworks.cc
[3] http://opensoundcontrol.org
[4] http://jeraman.info/illusio

6.2. Effect Comprehension Degree

Considering the effect comprehension degree questions, 68% of the participants marked 3 or 4 (35% answered 3 and 33% answered 4) in a scale from 1 to 5 (where 1 is "I do not agree" and 5 is "I completely agree") and only 13% marked 5.

This result shows us that the system's output effects were not evaluated by the audience as well as the user's actions. It could be an interesting point in a future redesign of the instrument. The calculated average value related to the effect axis was 2,91.

To measure whether the participant actually understood the system's effects, an open question was used: "Describe in few words how does the system work". The written answers well described the effects of the system.

6.3. Mapping Comprehension Degree

In respect of the mapping comprehension degree, 41% of the participants marked 4 and 35% marked 5 (considering a scale from 1 to 5, where 1 is "Did not understand" and 5 is "Completely understood"), which shows that the mapping was considered well understood by the majority of the audience.

The open question used in the Mapping degree was the same used in the Effect degree. However, we could perceive here that only a few participants mentioned what the user did for reaching system's outputs, fact that has hindered the accuracy measure of mapping results. The calculated average value related to this axis was 3,8.

6.4. Intention Comprehension Degree

When the issue is the intention comprehension degree, 79% of the participants marked 4 or 5 in a scale from 1 to 5. However, once again, the usage of open questions did not help to verify the accuracy of these results, as the answers were very abstract and confusing, hindering any attempt to match positively or negatively perceived and actual understanding. The calculated average value related to this axis was 3,87.

6.5. Error Comprehension Degree

When asked whether the system correctly responded the user's actions, concerning the error comprehension degree, 30% of the participants marked 5 and 59% marked 4 in the 1 to 5 scale, what seems suitable as the system and the performer actually presented only a few errors during the performance.

However, when a yes-no question was asked about the system's and the performer's errors, 74% of the participants answered that they have not perceived any error, which may indicate that the system does not highlight occurrences of errors to the audience. This fact also seems to justify why participants thought the system properly responded the user's actions.

The average value related to the error axis was 2,67, calculated using an average between the first mentioned scale-based question and the percentage of the participants that answered Yes on the yes-no questions related to error – and who has correctly justified it in the open questions.

6.6. Instrument Classification and Datasheet

Finally, classifying the instrument according to Reeves' taxonomy, two scale-based questions were asked about cause and effect subject. The scale ranged in a continuum between 1) "Invisible/absent" to 5) "complex/excessive", representing respectively "hidden" and "amplified" in the scale proposed by Reeves. The final average values were, respectively, 3,17 and 3,39 (between "partially revealing" and "transforming" according Reeves), which led to classify the instrument interaction model as expressive.

According to these results, the Illusio datasheet was created, as shown in Figure 5.

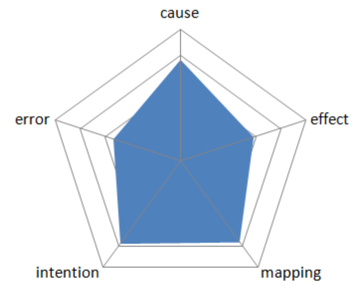

Figure 5. Illusio datasheet

It is important to highlight that all above mentioned data is available in Internet [5] as references for other works, including the video demo used in the data collection step [6].

7. DISCUSSION

The proposed approach was considered successful since it showed to be a practical and structured method that has provided useful information towards a more reliable analysis and comparison of DMIs.

Although the results and the final datasheet provided some information about how it would be possible to improve the prototype, it is important to notice that it would be more meaningful if we had compared them with datasheets of different DMIs (or yet of different versions of Illusio prototypes), what would provide a more objective way to analyze and compare them. However, as a work in progress and always aiming the methodology improvement, we believe that the developed research generated a set of relevant results that will be discussed as follows.

Considering the profiling step, it is thought that deepening the profiling techniques and focusing on a more specific audience profile could give the process more refined results about the instrument.

Assuredly, the most problematic step was the data collection step. Regarding it, although the open questions used in the questionnaire provided good parameters for reducing the gap between perceived and actual understanding it did not properly work for all cases due to the fact some answers were abstract or superficial, which did not give any hint about how to match both understandings.

On the other hand, this usage has brought a collateral positive point as comments, suggestions and criticisms received that could be used for future phases of instrument re-design.

It is also important to highlight that due to the scope of our approach on analyzing only the audience's understanding about the instrument being evaluated, we could have lost important information that is related the other aspects (aesthetic, cognitive) not studied in this paper. Thus, the more effective we wanted this evaluation process to be, the more analyzed and considered these aspects should also be.

[5] http://www.cin.ufpe.br/~fcac/nime2012
[6] http://youtu.be/CAiVWvVFaqI

Finally, inside the data visualization phase, concerning the classification according to Reeves et al. taxonomy of instrument interaction models, it is important to consider that as it is based on relations of two different variables (cause and effect) - a 2-dimension graph - we lose potential useful information due to the labeling process that reduces it to a one-dimension information. Thereby, a DMI labeled as "Secretive", and that presents a high cause-effect correlation could be classified in the same group which contains another "Secretive" DMI with a more pondered average, which is much closer to other labels.

8. CONCLUSION

This work presented an approach for evaluating DMIs considering the audience's view, based on the combination of ideas and methods of previous works, aiming to contribute towards building a more complete and deeper generic DMI evaluation methodology.

Despite its application generated useful results regarding DMI evaluation in the context of audience's view and about how to improve the Illusio system itself, it is important to highlight that the method is still under continuous development. Thereby, other case studies and iterative reapplications are necessary - including case studies comparing different versions of Illusio and comparing Illusio with well-known DMIs - what would allow us to make systematic analysis and comparison of them.

A critical point for improvement in this study is the technique used for reducing the gap between actual and perceived understanding, which was not suitable for all cases. For future work, we plan to change from asking questions to presenting statements that will be considered true or false by the audience - following the Likert scale [23]. With this approach, we believe the results will be more objective, and the actual understanding could be closely reached.

Regarding the ongoing research about a more generic evaluation methodology [2], we also propose to merge the approach presented here with the early approach that considered the performer's view, providing a more complete and deeper way to visualize the DMI, enriching the whole evaluation process.

Finally, it is necessary to highlight the importance of this evaluation process as a phase in the cycle of user-centered design of a DMI, where user (both performer and audience) feedback is constantly used to improve the system.

9. ACKNOWLEDGMENTS

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