All You Need Is LOD : Levels of Detail in Visual Augmentations for the Audience

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ABSTRACT

Because they break the physical link between gestures and sound, Digital Musical Instruments offer countless opportunities for musical expression. For the same reason however, they may hinder the audience experience, making the musician contribution and expressiveness difficult to perceive. In order to cope with this issue without altering the instruments, researchers and artists have designed techniques to augment their performances with additional information, through audio, haptic or visual modalities. These techniques have however only been designed to offer a fixed level of information, without taking into account the variety of spectators expertise and preferences. In this paper, we investigate the design, implementation and effect on audience experience of visual augmentations with controllable level of detail (LOD). We conduct a controlled experiment with 18 participants, including novices and experts. Our results show contrasts in the impact of LOD on experience and comprehension for experts and novices, and highlight the diversity of usage of visual augmentations by spectators.

Author Keywords

audience experience, augmented reality, visual augmentations, level of detail

CCS Concepts

•Applied computing → Performing arts; Sound and music computing; •Human-centered computing → Laboratory experiments; *Mixed / augmented reality;*

1. INTRODUCTION

Audience experience has become an important aspect in the creation of Digital Musical Instruments (DMIs), either as an evaluation method [2] or as a dimension which should be addressed at the design or performance stages [18]. In fact, DMIs may degrade the audience experience in performances, compared to acoustic instruments. Because they break the physical link between gestures and sound, they degrade the attributed agency, i.e. the perceived level of control of the musician [6].

Furthermore, their diversity and complexity makes it difficult for the audience to build a familiarity with every instrument. As an attempt to compensate for these issues and restore the audience experience, artists and researchers alike have designed techniques which augment the instruments with additional information. While these techniques explore different modalities (visual, haptic, auditory) and address different aspects of the performance (technical, gestural, intentional), they offer the same fixed level of information to all spectators.

However, augmenting the audience experience implies considering spectators from an individual perspective. The information needed by each spectator can differ depending on their personal sensitivity and expertise. In order to ensure an optimal experience for spectators, we propose to allow the audience to dynamically change this level of information using visual augmentations with variable levels of detail (LODs).

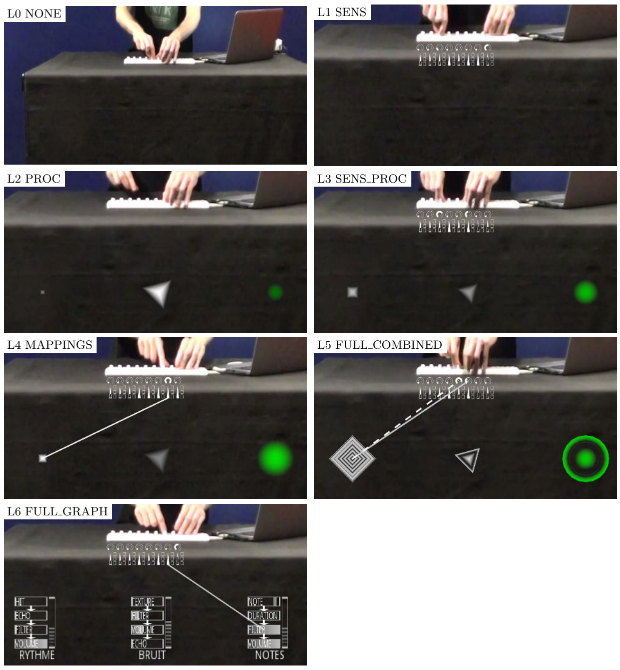

Figure 1: The 7 *global* levels of detail (LODs) used in our experiment, as seen by the participants. Each is built as a combination of *local* LODs for the Interface, Mappings and Processes sections (details in 2.2 and 2.3).

[1]All stimuli, illustration videos of the conditions, anonymised raw results, statistical analyses and implementation demos can be found here : `http://o0c.eu/ONA`

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1.1 Augmenting the audience experience

A number of augmentation techniques for spectator experience have been designed. Perhaps the simplest is the organisation of pre-concert demonstrations, such as described by Bin et al. [8]. More common is the use of visual projections that represent the instrument structure and parameters or musician's gestures. Examples can be found in many electronic performances, with accompanying visuals displaying changes in sound processes as abstract or figurative elements. Perrotin et al. have proposed to display the musical controls of musicians in an orchestra with a video projection, to help the audience perceive the actions of each orchestra member [17] by representing both gestures and musical parameters. Similarly, Correia et al. discuss the role of visuals in live performances [11] and insist on the importance of showing both the gestures (interface) and parameters to the audience. Berthaut et al. [7] describe an augmented reality which can be used to reveal the mechanisms of DMIs. Haptic augmentations can also be created to increase the audience's engagement, as proposed by Turchet et al. [19]. All these augmentation techniques however only offer the audience fixed levels of detail.

Benford et al. [5] combine projected visual augmentations during the performance and visual/textual augmentations on a mobile app after the performance, which allow spectators to access two levels of detail. Capra et al. [9] propose adaptive augmentations as part of a pipeline for augmented familiarity, but they do not provide an implementation or evaluate the impact of the described levels.

Contrary to these, in this paper we describe the design and evaluation of visual augmentations with controllable levels of detail, which allow the audience to choose the amount of information they want.

1.2 Level of detail

The level of detail (LOD) approach originates from the field of computer graphics where it is used to adapt 3D models and scenes complexity in order to reduce rendering load. It can also be found in the field of information visualisation to adapt quantity of information in order to limit visual overload. In the HCI literature, LODs allow users to access different levels of complexity in the interface, such as with Zoomable User Interfaces [3], or in a musical context to build and manipulate complex musical structures [1].

In our case, LODs allow spectators to adapt the amount and the type of information provided by visual augmentations about the interactions of a musician with a DMI.

1.3 Contribution

In this paper, we describe the design and implementation of visual augmentations of Digital Musical Instruments for the audience with dynamic and controllable levels of detail. Through a controlled experiment based on a protocol proposed in [10], we study the effect of LODs on the audience experience, and investigate how they would be used in performance settings[1].

2. DESIGN AND IMPLEMENTATION

In this section, we describe the design and implementation of visual augmentations with controllable levels of detail for Digital Musical Instruments (DMIs).

2.1 Visual augmentations

Throughout this paper, we use the term *visual augmentations* to describe graphical representations of the controls and mechanisms of a DMI, which are superimposed on the physical performance with the help of an augmented reality display. The purpose of visual augmentations is to reveal aspects of DMIs that are not easily perceived by the audience due to their lack of familiarity with them and the absence of physical link between gesture and sound. This includes subtle and/or hidden gestures sensed by the interface, complex or unusual mappings between the gestures and the various controllable parameters and the dynamic behaviour, potential range of output and internal structure of a DMI. Following what Berthaut et al. proposed [7], our visual augmentations represent the three main sections of the instrument : 1) the physical *interface* composed of sensors (e.g. a MIDI control surface); 2) the *mappings*, i.e. the connections between sensors and musical parameters (e.g. the first fader controls the volume of the first audio track); 3) the *processes* (e.g. tracks, loops, patterns) that generate the sound.

An important aspect of visual augmentations is that they do not restrain the design of DMIs. Instrument designers and musicians are free to choose their interfaces, mappings and processes with expressiveness in mind, without worrying about the transparency [12] of the musicians' actions or the familiarity [13] of the audience with the instrument.

However, the potential complexity of DMIs implies that visual augmentations may become too detailed if one aims at representing all their events and components, which might in turn degrade the spectator experience that we are trying to improve [16]. Spectators might also prefer more or less detailed information for aesthetic reasons and at various times in the performance.

To that extent, we propose to define dedicated levels of detail for each section (Interface, Processes, Mappings) of the visual augmentations. These *local LODs* can be chosen independently or combined as *global* LODs such as the ones we describe in section 2.3.

2.2 Local LODs

The augmentations specifically designed for a section of the instrument are called *local LODs*. We propose 4 levels of detail for the Interface section, 3 levels for the Mappings section, and 5 levels for the Processes section[1]. Each *local LOD* features a level 0 in which the section is not augmented. If all three sections are at level 0, no information is added to the performance. One should note that the information provided by each level can be displayed in different ways, the representations proposed in our implementation are only one of the many possibilities that artists can explore.

In the **Interface section**, Level 1 only indicates the global activity, e.g. when the musician performs a gesture sensed by the system. Level 2 represents the activity of each sensor of the physical interface, allowing one to perceive fast and complex gestures such as bi-manual or multi-finger interactions. Level 3 describes both the activity and the type of each sensor (discrete/continuous, shape of sensor ...). Level 4 adds a representation of their values and range.

In the **Mappings section** level 1 only describes to which processes the sensors are connected. Level 2 refines the connection to the parameter level. Level 3 adds a representation of the operation or series of operations which transform sensor values into parameters values [12], e.g. scaling, inverting, combining and so on.

In the **Processes section**, Level 1 visualises the output of the system as a whole, merging the activity of all sound processes. Level 2 provides a detailed activity for each process of the system, e.g. a distinct shape whose size indicates the volume of the corresponding sound process. Level 3 adds a dynamic representation of parameters (i.e. inputs) that can be controlled on the processes. Level 4

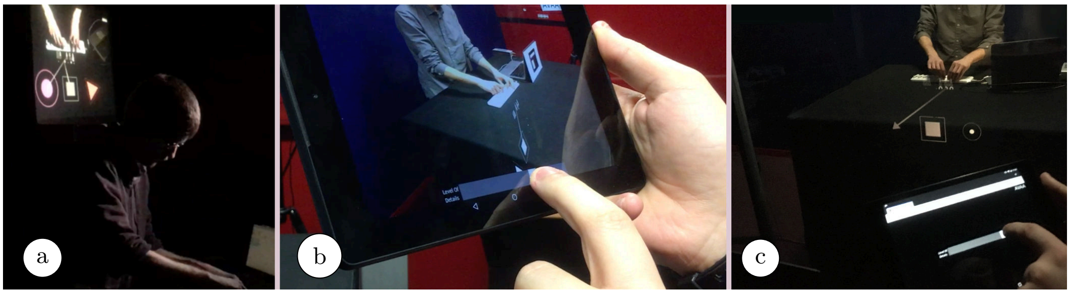

Figure 2: Possible implementations[1] of visual augmentations with LODs : a) Shared close-up with Video AR projected behind the musician and artist defined LOD, b) Mobile AR with individual LOD control, c) Spatial AR with an optical combiner shared between all spectators and mobile control to vote for the LOD.

adds parameters names, types and values range, i.e. as performers would see them when performing with a GUI. Level 5 provides a detailed representation of the complete internal graph of audio synthesis and effects that generate the sound of each process. It corresponds to what the musician would access when designing their instrument, and is potentially similar to the mental model they have when performing.

2.3 Global LODs

Global LODs are a combination of *local LODs*. They provide the spectators with a convenient way to control the level of detail by modifying several sections at a time : Interface (I), Mappings (M) and Processes (P). For instance, "*SENSORS* (I4-M0-PO)" is a *global LOD* called "SENSORS" and uses Level 4 for the Interface section and Level 0 for the others.

In the following study, we use 7 global LODs with increasing quantity of information (See Figure 1).

NONE (I0-M0-P0) provides no information at all. The performance remains unchanged.

SENSORS (I4-M0-PO) amplifies the gestures performed by displaying representations of the types and values for all sensors of the interface. It is therefore similar to the level of details provided by Turchet and Bartet [19] with haptics, and Perrotin et al. [17] for visuals. In the case of our study, faders, knobs and buttons of a MIDI controller are displayed.

PROC (I0-M0-P2) displays the sound processes of the instrument as separate shapes with graphical parameters associated to extracted audio features (loudness with size, pitch with color hue, brightness with color luminance), allowing spectators to identify the broad structure of the instrument and the activity of processes. This LOD corresponds to the representations traditionally used to illustrate electronic music performances (e.g VJiing) and defined as audiovisual entities by Correia et al. [11].

SENS_PROC (I4-M0-P2) shows both amplified gestures and the activity of separate processes. It provides information on both the interface and processes of the instrument, without detailing its internal structure or behaviour.

MAPPINGS (I4-M1-P2) adds information pertaining to how sensors are mapped to the sound processes. It shows when a sensed gesture has an effect on a sound process but not what effect it has, i.e. not what is exactly controlled by each sensor. In our implementation, mappings are displayed as lines between sensors and processes, which appear when a control is performed and then fade out. It is similar to the level of information proposed in the Rouages project [7].

FULL_COMBINED (I4-M2-P3) refines both the Mappings and Processes sections. It shows which parameter are controlled by each sensor and displays both the parameters and activity of the processes. In our implementation, each process is represented by a composite shape with an outer ring displaying the input parameters (i.e. gain with size, filter cutoff with color luminance, position in sample with rotation, delay feedback with shape repetition, pitch with color hue), while the activity is shown by an inner graphical element. This level is similar to the augmentations described by Berthaut et al. [6].

FULL_GRAPH (I4-M2-P5) provides a complete overview of the instrument with parameters names and value range, processes names and mappings between each sensor and the parameters. It corresponds to the mental model musicians might have of their instrument, with the exact structure, mappings and range of sonic possibilities. In our implementation, each process is labelled and displayed as a group of graphical sliders and buttons representing each parameter, with their names, value and range of values, and another slider serves as a VU-meter. Although this *global LOD* uses the maximum of each *local LODs*, we chose to limit the Mappings section to level M2 so that the amount of information remains reasonable. Similarly, the structure of the instrument used in our study is essentially a stack of samplers and effects with one parameter each, so that level P5 adds very little information compared to level P4. This structure was chosen in order to reduce the gap in quantity of information from the previous *global LOD*, i.e. we do not add a complex audio graph in addition to the details on parameters when going from *FULL_COMB* to *FULL_GRAPH*. FULL_GRAPH can be seen as similar to approaches where the full complexity of the instrument is shown such as in live-coding performances.

2.4 Implementation

The implementation of visual augmentations with controllable LODs raises questions regarding how to retrieve the information from the instrument and how to give the audience access to the LODs. In this paper the visual augmentations were implemented using the Godot game engine. The information, including activity and mappings, was retrieved in real time from the instrument, implemented with Pure Data, via OpenSoundControl messages. This extraction might however be more difficult with less open software, in which case only the lower LODs might be accessible, i.e. interface and processes activity but not the internal mappings. We envision multiple possibilities for implementing visual augmentations with LODs in a performance setting.

A first one relies on individual views of the augmentations, in order to allow each spectator to choose their LOD freely. This can be implemented with a mixed-reality headset or a mobile device as shown in Figure 2.b.

To avoid forcing the audience to wear or hold devices which may impair their experience, another possibility is to use a single spatial AR display, either projection mapping or an optical combiner (e.g. Pepper's ghost display), such as depicted in Figure 2.c, in which case viewers all perceive the augmentations spatially aligned with the physical instrument. Another possibility is to film and reproject a close-up view of the interface integrating the augmentations, as shown in Figure 2.a. This solution however moves the focus away from the physical performer. In these scenarios, only one LOD can be displayed at a time. LOD control may be performed by musicians or accompanying visual artists, so that they can modulate the audience experience during the performance. But the shared LOD can also be chosen by spectators. Voting system such as the one used in the Open Symphony project [20] may be used, in the form of a web interface accessible from their mobile devices, as depicted in Figure 2.c. In this case the displayed LOD reflects either the majority or the average vote.

Finally, an intermediary solution is to provide multiple views of the augmentations for groups of spectators, using video (i.e. multiple or multiscopic screens) or optical AR (mirrors at multiple angles). For each group, the LOD can be fixed at a different value, so that spectators can move towards or look at the display they prefer. A voting system may also be setup separately for each group.

3. USAGE AND EFFECTS OF LODS

In this section, we present an experiment that aims at evaluating the impact of LODs on audience experience and understanding, and studying the use of controllable LODs by spectators with different expertise. In order to retrieve accurate and individual data on spectator experience we chose to conduct a controlled experiment in the lab. We discuss the advantages and limitations of such 'in the lab' studies in more details in [10] and plan to address social and environmental aspects of public performances in a future work.

3.1 Procedure

18 participants (16 M, 2 F) took part in the experiment, aged of mean 29 (± 7.3 , min=20, max=43). Before the beginning of the experiment, they were presented with the details of the experiment and signed a consent form. Participants sat in front of a 24" screen, equipped with headphones and a Pupil-labs Core eye-tracking device (the details of the eye tracking are addressed in a forthcoming study). We measured their expertise with the instrument presented in the study using questions regarding their practice of DMIs, their use of graphical user interfaces similar to the one in Figure 1 and their use of control surfaces. We also asked how often they attended electronic music performances. This allowed us to compute an expertise score, and we used it to separate them into two groups : 9 experts and 9 novices. The experts had a music practice of 17.3 ± 6.4 years and an electronic music practice of 10.7 ± 7.3 years against 1.6 ± 2.6 of music practice and no electronic music practice for the novices. Experts had all used both graphical interfaces for music and control surfaces such as the ones presented in the experiment. Per year, experts claimed going to 12.8 ± 8.3 electronic music performances, while for novices the average was 0.6 ± 1.5.

3.1.1 Dynamic stimuli

The stimuli were videos of short performances with a DMI composed of a Korg NanoKontrol controlling a set of Pure Data patches with three sound processes (melodic, rhythm, granular texture) each with multiple parameters (See Figure 1). We designed 3 sets of mappings between the interface sensors (knobs, faders, buttons) and the parameters. Each set was intended to target a different level of contribution of the musician, i.e how much of the changes in the sound are due to them vs automated. The first set is completely manual so no changes happen without a gesture. It corresponds to the maximum contribution level. The second features automations for half the parameters, the rest being manipulated by the musician. In the third set of mappings, most parameters are automated and the musician is able to take control of some of them temporarily, giving the highest contribution to the computer.

In order to play the videos with dynamic overlapping visual augmentations, we designed the experiment in the Godot game engine. Videos were played synchronised with the playback of control data recorded in Pure Data, so that the sound and the visual augmentations were generated dynamically during the playback. This technical setup gave us the flexibility to play the video footage of a performance and to accompany it with arbitrary audio processes and visual augmentations in real time. The experiment lasted around 45mn and was composed of 2 blocks.

3.1.2 Block 1 : fixed LODs

In the first block, participants watched 7 LODs x 3 contribution levels = 21 videos of short performances (20s). Each video was followed by a questionnaire of 9 order-randomized questions to evaluate their experience and comprehension. The survey included only one objective question. We evaluated the ability of the participants to correctly detect the contribution levels that we induced by the mappings by answering the question "Who from the musician or the computer contributed the most to the performance ?". They also could choose 'both equally'.

The other questions were subjective and were based on 5 communication design issues introduced by Bellotti et al [4] and transposed to the spectator perspective by Gurevitch and Fyans [13]. We complement them with *Association* that targets the capacity to expose to spectators the contributions of the user (musician) and the system (DMI) [10]. These design challenges are well adapted to the evaluation of NIMEs as they allow for an assessment by components of the subjective experience of spectators. Participants answered on 7-step scales to the question *"To which extent do you agree with the following statement ?"*. Only the extreme values of the scales had a label : "I totally disagree" and "I totally agree".

- "In this video, I know when the musician is interacting with the instrument and when he is not."(Address)
- "In this video, I can see when the instrument is responding to the musician gesture and when it is not." (Attention)
- "In this video, I can see if the musician is controlling the instrument or if he is not."(Action)
- "In this video, I can see when the instrument is properly functioning and when it is not."(Alignment)
- "In this video, I can see if the musician or the instrument made a mistake."(Accident)
- "In this video, I can see the contribution of the musician and the one of the computer."(Association)

Finally, the participants had to report their personal rating of the performer's virtuosity and the overall performance on a 7-point scale.

3.1.3 Block 2 : dynamic LODs

In the second block, participants could change with the scroll wheel the LOD of the augmentations as the video

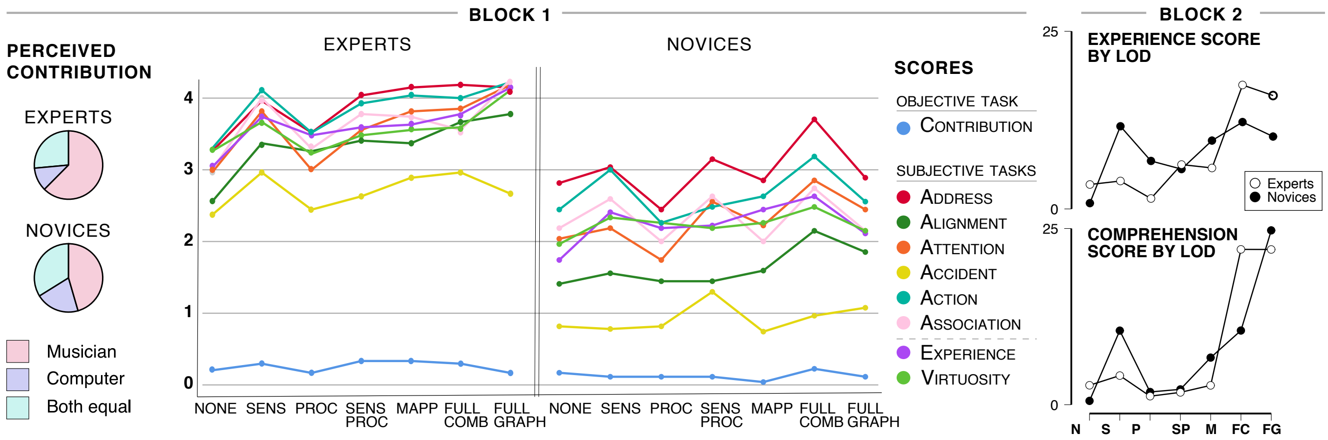

Figure 3: *Left* Regardless of the LOD, Experts perceived a higher contribution of the musician than Novices. *Center* LODs did not impact equally the subjective perception of the interactions. Experts reported higher evaluations of the subjective dimensions of the spectator experience. *Right* When participants could choose their favourite LODs in real time, strategies emerged as illustrated. They were refined in the interviews.

was playing. In a first task, they watched 3 short (60s) performances and were asked to select the LOD that gave them the best experience, i.e. that they preferred. In a second task, they watched the same performances and were asked instead to choose the LOD that allowed them to understand best what the musician was doing.

3.2 Results

Data was recorded, anonymised and stored in real time during the experiment by a bespoke experiment software developed in the Godot game engine. Subjective reports were obtained via likert scales and were analysed with parametric tools when the normality assumptions were met. The analyses were conducted under the common frequentist paradigm and were combined to Bayesian statistics [15]. A Bayes factor is reported as BF_{01} when data better support the null hypothesis and as BF_{10} when data support the alternative hypothesis (note that '01' becomes '10'). For example, the statement $BF_{10} = 2.4$ means that the data are 2.4 times more likely to occur under a model including the corresponding effect. The posterior odds have been corrected for multiple testing by fixing to 0.5 the prior probability that the null hypothesis holds across all comparisons. Analyses were performed with SPSS v25, R studio 1.2 and JASP [14].

3.2.1 Block 1 : fixed LODs

Analysis did not revealed any group effect and any effect of the levels of detail (LODs) on the objective task. Overall, the evaluation of the factual contribution ratio between the musician and the computer proved difficult.

Still, from a subjective perspective, an interesting group effect ($\chi^2 = 12, p = 0.002, BF_{10} = 11$) showed that Experts considered the musician contributed more than the computer in 62% of the stimuli compared to 45.5% for Novices (Figure 3 - *Left*).

As depicted in Figure 3 - *Center*, experts reported higher evaluations of the subjective questions. Regardless of the group, the *Accident* was the least rated, meaning that participants were not so confident in their capacity to detect errors. The effect of the LOD was revealed on most of the subjective questions ($all\ p{-}values < 0.027, all\ BF_{10} > 6$), with the exception of Accident and Virtuosity ($all\ p - values > 0.22, all\ \ BF_{01} > 4$). Two LODs were particularly effective, *SENS* and *FULL_COMB*. Reading the graph (3 - *Center*) from left to right, compared to *NONE*, the control condition, *SENS*, the level of detail exposing the sole sensors activity, presents a significant boost in all dimensions, then *PROC* exposes an equivalent score to *NONE*. From *SENS_PROC* to *FULL_COMB* a rather linear progression is observed. In the Experts group, the progression tends to extend to *FULL_GRAPH*. In a much more volatile distribution, the results for the Novices group nevertheless present *FULL_COMB* as the most effective. The efficiency of *FULL_COMB* for Novices is also supported by an analysis of the difference with the Experts' scores. For 6 (out of 9) dimensions, the smallest difference is measured when visual augmentations are presented with *FULL_COMB*. This result is a good illustration of the expected role of visual augmentations, compensate the lack of expertise of novices for a better experience.

3.2.2 Block 2 : dynamic LODs

The score for these tasks was calculated by accumulating the time participants spent using each LOD. Both tasks, experience and comprehension, show comparable evolution characterised by a minimum for the control condition *NONE* and a maximum for the higher LODs (Figure 3, Right). A decisive effect of LODs was found ($F_{(6,90)} = 9.94, p < .001, BF_{10} > 10000$) but with no difference between the groups ($BF_{01} = 4$). Novices favoured *FULL_COMB* and *SENS* for experience and *FULL_GRAPH* for comprehension. Experts chose the highest LODs for experience and *FULL_COMB* and *FULL_GRAPH* for comprehension.

3.3 Discussion

LODs affect subjective comprehension. The interviews confirmed and extended the quantitative analyses. Despite the absence of effect of LODs on factual perception, participants favoured levels *FULL_GRAPH* and *SENSORS* for understanding the performance, especially when the music got more complex with many fast changes in the sound. This suggests that LODs influence the subjective comprehension of spectators, even if their factual understanding is not improved. It also suggests that amplifying the gestures (*SENSORS* level) might be more informative than displaying the activity of processes alone (*PROC* level).

The role of expertise. Our study reveals interesting insights on the nature of expertise in DMI spectators. Results of Block 1 showed that experts perceive an higher contribution of the musician when novices perceive a higher contribution of the computer. Also, experts put more trust in their personal representation of the interactions as proven by their higher evaluation of the Bellotti-Fyans challenges. This contrast is confirmed in Block 2 where only novices favoured the *SENSORS* LOD over no augmentations for a better comprehension and experience (Fig. 3 - *Right*), as if experts already had an internal representation of the interactions with the sensors and therefore did not need that LOD. Apart from *SENSORS*, both experts and novices mostly utilised *FULL_COMB* when they could choose their favourite LOD. But when they had to choose a LOD in order to better understand the interactions, experts equally used *FULL_COMB* and *FULL_GRAPH* when novices massively favoured *FULL_GRAPH*. As both groups scored poorly in the objective task in Block 1, whatever the LOD, these preferences in LOD are to be taken as subjective beliefs in a facilitation of understanding rather than a factual help.

Errors and virtuosity. The absence of effect of LODs on both the *Accident* dimension (i.e. the feeling of being able to perceive a potential error) and the virtuosity ratings underlines the crucial role of error perception in the emergence of a judgement of virtuosity [13]. A solution to this issue could be inspired by music video games where the virtuosity is materialised by screen indications of combos of successful moves. Such informative contents are efficient and spectacular but imply the restriction of any improvisation or non-expected techniques. Another solution would be to design LODs that inform on the virtuosity, such as visualisations of input complexity or extra-ordinary values for controls and musical parameters.

LOD choice strategies Strong differences in the choice of favoured LODs at the individual level were revealed by the data and refined by the interviews. When analysing the answers of participants regarding how they would use the LODs in public performance, we can distinguish 3 clear strategies: **all or (almost) nothing:** 4 participants claimed they would alternate between the maximum LOD (or just start with it) in order to form a mental image of how the instrument works (i.e. its capabilities) and then go back to no augmentations or to the *SENSORS* level, in order to focus on the musician's gestures. **adapting to complexity / performance:** 4 participants claimed they would use LODs as a way to adapt to the complexity of the instrument or music, or change it depending on the musician playing; **progression:** 2 participants mentioned that their appreciation of LODs evolved over time, the more complex ones becoming more enjoyable and accessible, so that they would end up not going back to the lower LODs. One must note than even within these strategies there are interpersonal variations, again highlighting the utility of a controllable LOD on visual augmentations.

4. CONCLUSION

In this paper, we investigated the design of levels of detail (LODs) in visual augmentations and their effect on the audience experience. While our results provide useful insights, we believe the controlled experiment approach that we took could be combined with in the wild study of performances. As future work, we think that augmentations with LODs should be extended to other interfaces, e.g. gestural controllers or graphical interfaces such as live-coding, and that the effect of aesthetic choices should be investigated.

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