# Designing collaborative musical experiences for broad audiences

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## ABSTRACT
This paper reports on the design and audience evaluation of a collaborative interactive music system titled *Polymetros*. Designed for broad audiences, *Polymetros* aims to enable users without musical skills to experience collaborative music-making. First, we describe our design approach with reference to related research. A particular interest was to investigate how to provide novices with individual musical control within a collaborative context. We then present an audience evaluation that was conducted during an exhibition at a major art museum in the UK attended by large numbers of the general public across the age range. The results lead us to evaluate our design approach and reflect on implications for facilitating collaborative music-making for broad audiences. Furthermore, the findings provide interesting indications how the context of a public exhibition setting affects the audience interaction with such an interactive multi-player experience.

### Author Keywords
Collaboration, interactive music systems, interaction design, multi-user interfaces, public creativity, audience experience, field study

### ACM Classification Keywords
H.5.3. Group and Organization Interfaces: Evaluation/methodology; H.5.5. Sound and Music Computing: Systems

### General Terms
Human Factors; Design

## INTRODUCTION
This paper discusses results from an ongoing research project that investigates how to transfer the traditionally exclusive experience of musical collaboration to a much broader audience using interactive technology. In contrast to Western art music, where collaboration mainly aims for a particular musical result according to 'high art' aesthetic criteria, we are interested in the creative process of making music as an end in itself. By considering music-making as an enjoyable group activity rather than an expert profession the idea of *collaborative musical experiences* refers to enabling people without particular musical training to experience being part of a creative, collaborative musical process. Common attributes characterising similar approaches in the existing literature include 'open-ended' [1] [5], 'social' [2] [20] and 'democratic' [17] [22]. As part of this project, we developed the interactive music system *Polymetros* which is designed as an audience experience for exhibitions, festivals or public workshops while serving as a flexible research tool to investigate and evaluate our strategies under such real-word conditions.

Since such contexts are generally intended to reach out to a wide public, our target audience is characterised by a broad range of skills, experience, and age. However, particularly with regard to musical abilities, it has to be considered that large parts of the audience in a public context cannot be assumed to have honed musical skills gained through formal musical training such as learning a musical instrument. In the following paper we refer to this group as musical *novices*.

Therefore, a particular interest was to investigate how to provide novices with opportunities to experience and maintain control over their musical activities and how these contribute to the collaboratively created music. This approach was based on our research claim, informed by relevant literature, that feeling part of a collaborative musical process is closely related to the sense of control each participant has over their particular contribution. Moreover, we consider individual control as an essential pre-condition for active musical collaboration and therefore as an essential design goal for interactive systems aiming at facilitating such experiences.

The paper will first outline how our general approach and the particular design of the *Polymetros* system was informed by related research and then present the results of an audience evaluation conducted at a public exhibition event.


*C&C'13*, June 17 - 20 2013, Sydney, NSW, Australia

## CONTEXT AND RELATED WORK

Reflecting on what constitutes the satisfaction of making music, Atau Tanaka argues that the musicians' satisfaction is directly related to the sense of how their actions manifest in the resulting music. This includes the direct feedback of the instrument as well as "the identifiability a musician maintains in feeling the contribution his part is making in an ensemble" [17]. In accordance to the general idea of the 'sense of agency' which refers to the sense of control over one's own actions [7], Tanaka calls these notations 'sense of musical agency' [17]. Considering this concept with regard to a scenario involving musical novices clearly illustrates the challenge we face when designing interactive technology that aims at transferring such an experience to a broad audience: Unlike an ensemble consisting of musicians who spent years of training in order to control and shape their instrument's feedback into a distinctive voice within the ensemble context, collaborative musical experiences can not rely on skills and practices that need to be developed over a long period of time. Therefore, interactive technology steps in to bridge these technical demands by facilitating possibilities for musical control and interaction that are achievable for everyone.

A common strategy is the use of pre-produced musical material: Instead of enabling the *creation* of musical content, the system provides high-level control possibilities that allow the participants to influence its musical output. Multi-person applications that have explored such an approach include Robson's *Sound Toys* [15], the *Jam-O-Drum* system [3] or MIT Media Lab's *Musical Navigatrics* [13]. Even though these systems differ significantly in terms of appearance and used sensor technology, they share the same basic principle: Each participant's interaction is mapped to a high-level parameter such as volume or timbre allowing them to modify a particular element of a pre-composed sound set. A common critique of such an approach is that the user's possibilities to have an impact on the musical outcome are often strongly restricted in favour of an intended, predetermined output. Sergi Jordà argues that by "seeking to guarantee a complex or predefined musical output, many of these [sound interactives] do not give to their interactors more than a couple of bits to play with" [10]. Also Weinberg criticises the deficiency of many novice systems for not allowing their players to "truly contribute meaningfully and creatively to the composition, but rather they are only allowed to manipulate and control pre-composed material" [19]. Moreover, it is questionable whether such restricted possibilities of influence are sufficient to convey a 'sense of musical agency' and the experience of actually *making* music.

In accordance with his critique, Jordà directed the development of the collaborative interactive tabletop system *Reactable* [11], which has became quite well-known over recent years. The design goals were to create a "state-of-the-art interactive music instrument" that allows its players total control without being based on pre-produced material or presets. It should be suitable for skilled electronic musicians in concerts as well as for complete novices in installations without instructions [11]. The *Reactable* relies on the metaphor of a modular synthesiser whereas the different available modules are represented by tangible objects. These include audio generators like oscillators or sample players, control modules like LFOs (Low frequency oscillator) and sequencer objects as well as audio effects such as filters or delays. The modules can be dynamically patched together on the tabletop surface while their particular properties, mutual dependencies and the overall data flow are visualised via rear projection. In this way, several people can collaboratively build up a modular interactive musical environment for real time sound synthesis. Being a highly versatile and powerful environment for experts, we consider it as less appropriate for music making *among* novices. Even if suitable to allow a novice to experimentally explore electronic sound synthesis, a collaborative creation undertaken by several players simultaneously seems to require a profound understanding of the underlying principles and various interdependencies among the available objects.

Unlike *Reactable*, Weinberg's collaborative music systems are explicitly designed for novices. Avoiding the use of prerecorded audio, the musical output of the *Beatbug Network* [20] is entirely based on material created by the users during their playing experience. Each player is provided with their own bug-shaped, hand-held interface allowing them to enter a short rhythmic pattern which is then sent to an other player's bug chosen at random. The receiving player can decide whether to transform it by applying audio effects via the bug's bend-sensor antennae and pass the modified version on or keep the received pattern playing as is and contribute their own pattern. In a turn-based manner, all group members are able to contribute their own phrase while maintaining the transformations they like. Similar to Weinberg's *Squeezables* [21], the *Beatbug Network* is also based on the concept of interconnected musical networks (IMNs) that allow players "to influence, share, and shape each others' music in real-time" [20]. Due to the complexity of the interactions, both systems were mainly suited for structured performances that follow a pre-composed score being rehearsed in a series of guided workshops rather than open-ended audience experiences in a public context [19]. But Weinberg's network-based approach reveals an interesting perspective on the relevance of a personal contribution in such environments: Informed by his design experiences, Weinberg recommends restricting the level of interdependency in order to avoid "uncertainty about the individual control of each player" [21]. Therefore, a player should not be able to modify a peer's phrase beyond recognition, as its creator might experience a loss of control and influence on the overall musical result. This can make the players "feel disconnected from the music they created, as their detailed idiosyncratic contribution might be eliminated" [19]. These claims closely correspond to Tanaka's concept of musical agency and highlights the importance of providing players with opportunities to create and maintain clearly identifiable contributions within a collaborative musical context.

## POLYMETROS

We now come to a description of *Polymetros*, which is an interactive, table-based music system designed as an audience experience for 3 - 4 participants. Every player is provided

with their own physical user interface allowing for an individual musical contribution within this collaborative context (Figure 1).

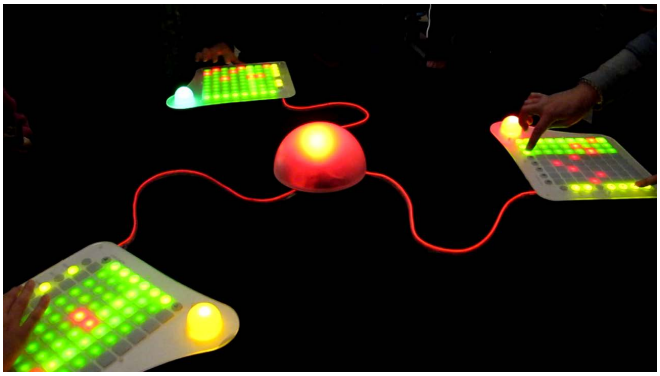

**Figure 1.** ***Polymetros***

## Design strategy

In light of findings from our literature review as discussed in the above section, we aimed to find a design approach that is neither based on pre-produced musical material nor on concepts or metaphors originating from a technical background. Therefore we considered an interaction concept relying on basic musical properties such as note, pitch and time. While the use of these commonly understood properties seems promising, it poses the challenge of how to enable novices to create their personal musical contribution on a basic musical level while also allowing for collaboration in such a way that manages the tension between 'cacophonic chaos' and an oversimplicity caused by highly restricted possibilities. From assessing and refining this strategy, the idea emerged to use *Minimal Music* as an inspirational basis for the system design.

Referring to a musical style mainly associated with the American composers Steve Reich, Phillip Glass, Terry Riley and La Monte Young [12], Minimal Music is characterised by the use of short repetitive musical phrases that are gradual modified in length, time signature or melodic shape. This leads to procedural transformations of the resulting music that often maintains a stable harmony while the main interest lies in the perceptible process itself [14]. As described by Phillip Glass, Minimal Music "no longer has a mediative function, referring to something outside itself, but it rather embodies itself without any mediation" [12]. This conception of music without an imposed higher sense being rather an end in itself closely relates to the idea of a *musical experience* as defined earlier. The music qualities are often characterised as 'hypnotic', 'trance-like' causing a sense of timelessness. Beside that, Minimal Music implies a 'democratic' attitude towards players as well as musical material: There are no soloists or lead instruments as no sound has any greater importance than another [12].

As these qualities, the musical structure, and the underlying techniques of Minimal Music closely corresponded to our intended scenario, we decided to use specific properties of this musical 'expert-domain' to inform the design of an interactive system for a broad audience. In practical terms, we aimed to allow for every player to create and control a repetitive musical phrase which would become their personal contribution to a constantly evolving, collaborative musical output. Besides editing the actual notes of the motif, they should be able to dynamically change tempo and time signature, add and remove notes/rests or shifting their phrase by a metrical entity in relation to their co-players' contributions. Inspired by minimalist composing techniques, these interventions allow the users to continuously deduce new variations and modify their contributions in a way that results in distinct alterations in the overall musical output.

However, it is important to note that this inspirational influence does not inevitably constrain the system's output to Minimal Music in the traditional sense. The derived control strategies provide a wider, versatile range of possibilities in terms of pattern-based music, for example in the studies reported in this paper we observed participants using *Polymetros* to create music almost in the style of *Dubstep*.

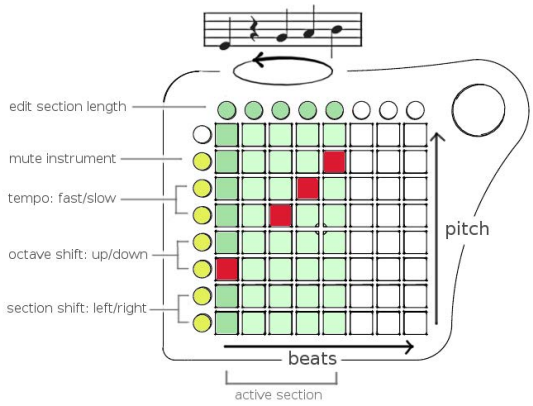


**Figure 2. A Polymetros instrument**

## System description

*Polymetros* is based on a software application written in MAX which controls a multi-user hardware interface combined with external audio equipment for sound synthesis and audio routing (Figure 3). The user interface is composed of 3-4 individual hardware devices which are connected to a central hub in a star-like topology. Each participant controls one device which features a grid of illuminated buttons. These devices are referred to as *instruments* (Figure 2). In order to implement the musical possibilities as described previously, every player can create and edit their musical phrase via a 8 by 8 button matrix where the x direction corresponds to time in beats and the y direction to pitch according to a chosen musical scale. In this case study a natural minor scale was used. The phrase is continuously played back in a loop while the actual playing position is indicated by a horizontal bar 'travelling' over the grid. Via the button row on top of the melody grid the user can dynamically change the loop length by defining the active section on the grid. The function buttons on the

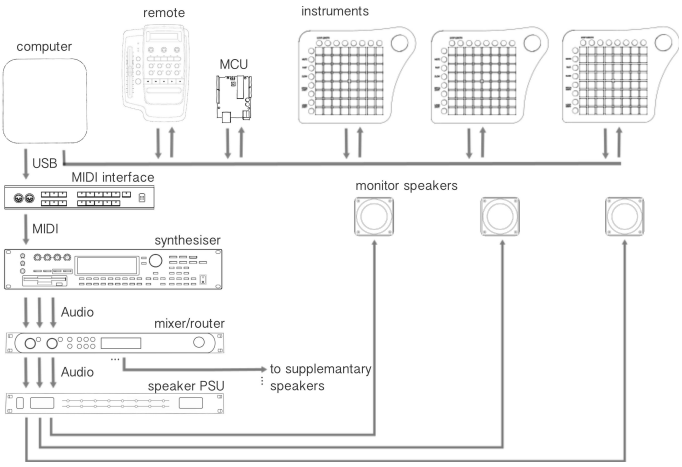


**Figure 3. Technical overview**

right allow the user to shift the active section, change tempo and octave register as well as mute the instrument's output. All functions and states of the interface are indicated by visual feedback via tri-colour LEDs embedded in the buttons. In addition, the instrument's cable connection to the hub flashes up every time a note is triggered on its grid. The sphere-shaped hub serves as the visual centre pulsating red with the beat as the metaphorical 'heart' of the system. In the reported study the sounds of the instruments were based on different mallet and pitched percussion instruments as these sound reasonably pleasing over a very wide pitch range. *Polymetros* is assembled on a round table with built-in loudspeakers that are hidden under the cloth stretched over the tabletop. These are mounted in such a way that each speaker is directed at one particular player serving as their personally assigned audio monitor. Using high-quality miniature speakers with a directional characteristic, an equal and well-defined listening situation can be provided for all players.

## CASE STUDY

### Pilot

Before the case study presented here, a pilot was conducted at an open studio event at the authors' university as part of the *Digital Shoreditch Festival 2012*. During this three-day exhibition the initial version of *Polymetros* was played by around 300 people while being video recorded and attended by one of the authors over the entire course of the event. The findings significantly informed the practice and methodological approach of how to conduct an 'in-the-wild' study of such a system within the context of a public exhibition. Beside that, they led to several improvements of the initial prototype including system reliability and user interface design as well as the implementation of often requested features such as individual tempo control.

### Context and setup

The user study was conducted during the exhibition of *Polymetros* at the *Digital Design Weekend 2012* which took place on September 22nd and 23rd at the Victoria and Albert Museum (V&A) in London, UK. Being part of the *London Design Festival*, this annual event is dedicated to contemporary digital art and design, including interactive installations, performances, demonstrations and workshops. Incorporating an open studio-like atmosphere, most of the exhibiting artists attended the event in order to demonstrate and discuss their work with audiences.

*Polymetros* was installed in a slightly darkened studio space alongside several other interactive and static artworks that required dimmed lighting. The system was positioned near a corner of the room sufficiently far from the walls to be approachable from all sides. Even though *Polymetros* was the only exhibit that incorporated sound within this area, the overall noise level was rather high due to the event's open studio character. On request of the curator the originally intended output volume had to be lowered to ensure that the sound is not audible in adjacent areas. Two video cameras were installed to record the user interaction from two different angles.

For conducting the case study we were aided by two assistants. This allowed the onsite researcher to mainly focus on contextual observation while the collaborators conducted and coordinated the other study-related tasks. These involved controlling the data logging system as described in the following section, handing out the questionnaires and providing some initial guidance on the interface functionality. Due to the open studio character of the event, the research team was also available to answer specific questions and discuss the exhibit with interested audience members.

### Methods and Data collection

Informed by the pilot study, we applied a mixed-methods approach using questionnaires, interaction logs, field observations and video analysis taking into account the contextual demands and the complexity of the setting.

#### *Questionnaire*

The questionnaire was designed to capture how participants rate different aspects of their playing experience. It was handed out by a member of the research team who approached visitors just after they finished playing with *Polymetros* with the request to fill in a questionnaire. Considering the given context, the questionnaire was designed to be completed in a short amount of time (1-3min). Beside gathering demographic data such as age and gender, it consisted of nine statements the participants were asked to rate on a 5 point Likert-type scale (not at all - slightly - moderately - fairly - very much). The questionnaire items are listed in Table 1. While the first two statements referred to the participants' musical skills and their experience with interactive technology (S1, S2), the other seven items related to the actual playing experience (E1-E7). During the two days of the exhibition the questionnaire was filled in by 150 participants (82 female and 68 male) from ages 5 to 66 (M = 24.3, SD = 14.05).

#### *Data logging*

For recording the user interaction with the interface a data logging application has been integrated into the *Polymetros* system. Via a remote control device the facilitator was able to activate and stop the data recording according to the time

| |
|---|
| S1: I am a musical person. |
| S2: I am experienced using interactive devices. (e.g. smart phone, tablet, video gaming) |
| E1: I felt part of a creative process. |
| E2: I felt in control. |
| E3: I felt connected to the other players. |
| E4: It was challenging. |
| E5: I liked the music we created. |
| E6: My playing was influenced by the playing of the others. |
| E7: I would recommend playing *Polymetros* to my friends. |

**Table 1. Questionnaire statements.**

a user spent playing on a particular instrument. Each created log contained an ID code indicating the number and instrument used, the start and end time as well as all edits made with the interface. During the study the most recent two ID codes of each instrument were shown on a display clearly visible for all members of the research team. This allowed the facilitator handing out the questionnaires to mark collected surveys with the corresponding ID if a log file has been created for this particular user. In this way, 63 of the 150 completed questionnaires could be allocated to their corresponding set of interaction data.

### *Field and video observations*

The observations were carried out by one of the authors for several hours on both days of the exhibition. They were mainly conducted from a standing desk located in the corner of the room which was also used to monitor the system functionality via a nearby computer display. Descriptive notes were taken referring to specific playing experiences of one or several audience members as well as events and activities of interest in the surrounding area. Beside participants' actions, the records included related gestures and behaviours such as laughing or head-nodding as well as age, gender and the corresponding ID code if available. Due to the close proximity to the users, we were able to note down verbal statements including spontaneous 'outlouds' of players, communication between audience members and comments made towards the research team.

In order to complement the field notes and examine specific aspects in greater detail 5 hours of the recorded video material were examined and annotated. In contrast to the field observations, studying the video recordings allowed us a more precise observation of how participants used their instrument's interface and what kind of musical contributions they created. It also enabled us to observe and review activities of interest that unfolded over a longer period of time such as a person's transition from an observer to an active player (cf. [16]) or details that were difficult to recognise on site due to the surrounding audience. Beside that, all relevant verbal data recorded by the camera-mounted microphone were transcribed.

## STUDY RESULTS

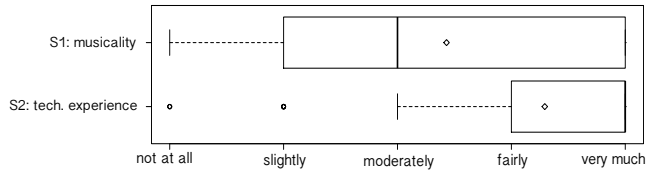


**Figure 4. Self-rating of musicality and technical experience (150 participants)**

The data of the questionnaire are shown in Figure 4 and Figure 5 . Each survey item is represented as an individual box plot showing median (bold, horizontal line within the box), first and third quartile (edges of the box), extreme values (whiskers) and outliners (empty dots) of the corresponding dataset. Beside that, the mean value is marked with a diamond symbol.

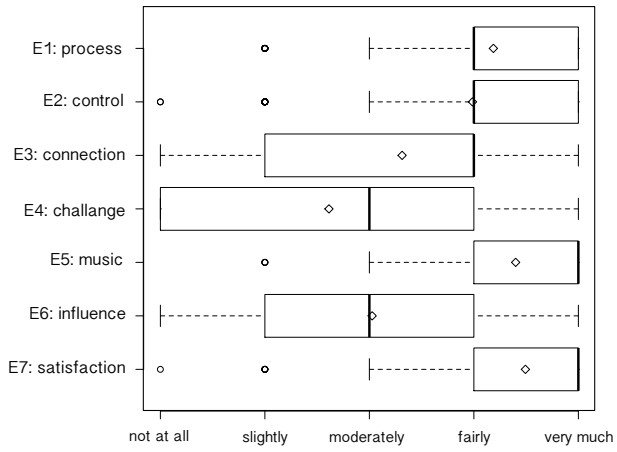


**Figure 5. Items related to playing experience (150 participants)**

### Experience questionnaire

While the self-rating of the participants' musical abilities is distributed over a wide range (S1), the majority of them considered themselves as experienced users of interactive technology (S2). Visual inspection of the experience-related items shows that most participants evaluated their playing experience as very positive: Designed to rate their overall satisfaction in an indirect way, 102 of 150 respondents stated they would *very much* recommend playing to their friends (E7). In addition, the majority of participants indicated that they were pleased with musical result (E5) and that they felt part of a creative process (E1). Beside that, we note a relatively high rank of the item 'feeling connected to the other players' (E3, median = *fairly*).

The high rating of the item referring to the players' feeling of control (E2) suggests that the chosen design approach is

generally appropriate for broad audiences. For exploring potential associations between individual survey items we used the Goodman and Kruskal's gamma coefficient as a dedicated measure of associations between ordinal variables with relatively few categories. Due to our specific interest in how the feeling of being in control is related to other qualities of the experience we calculated gamma for several combinations. We found highly significant associations between 'feeling in control' and 'feeling part of a creative process' (gamma = 0.56, $p < 0.0001$), 'feeling in control' and 'recommend playing to friends' (gamma = 0.50, $p < 0.0001$) and 'feeling in control' and 'feeling connected to other players' (gamma = 0.43, $p < 0.0001$). These findings indicate that experiencing control is related to other key qualities of the participants' playing experience such as feeling part of a creative process or feeling satisfied with the overall interaction.

With the term *dwell time* we refer to the period of time a participant was actively engaged with one of the instruments. Based on 294 interaction logs, the average dwell time was 3.3 minutes. We used the matched data set of questionnaire data with associated interaction logs as described previously to explore the relationship between the participants' dwell time and their survey responses to the items 'process' (E1), 'control' (E2), 'like' (E5), 'satisfaction' (E7). Calculating the Spearman's rank correlation coefficient for these combinations indicated no association between the dwell time and how the respondents rated such aspects in the experience questionnaire. This finding raised our interest in examining what factors were likely to be relevant for the participants' dwell time in our specific scenario and we devoted particular attention to this issue during the video analysis.

### Observations

Over the two day period of the exhibition, *Polymetros* demonstrated a strong appeal to the audience: While most of the time all three instruments were in use, the players were usually accompanied by a number of spectators surrounding the system. This situation seemed to establish an area of interest attracting further passing visitors to take a closer look at *Polymetros* whereas the majority stayed to interact with it. A similar social dynamic relating to interactives in public areas was reported by Brignull and Rogers referred to as the 'honey pot effect' [4].

In this rather crowded setting people appeared to start learning how to interact with the system by watching previous players: Several audience members were observed performing well-directed actions immediately after they took over one of the instruments, showing a prior understanding of the interface. Only complementary features such as length or tempo selection were left to be indicated by the facilitator. In general, we found that most of the audience members understood the interaction concept when given a short guidance by the facilitator. However, due to the rush of people over long periods of the exhibition it was not possible to provide guidance to all newly arrived players. While many visitors were able to discover the relevant aspects of their instrument on their own, a number of audience members could be observed having difficulties in understanding the interface.

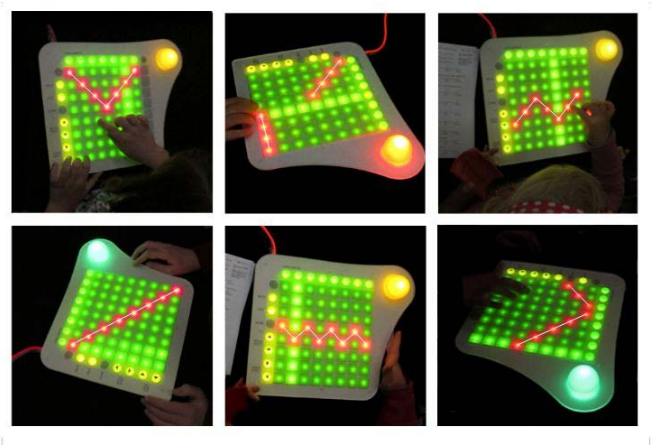

**Figure 6. Typical contributions**

These seemed to be caused by a lack of understanding of the loop-based concept of the user interface, as suggested by observations of inappropriate input gestures in relation to the sequential playback of the instruments grid.

A key experience for the participants appeared to be the moment of 'getting-it' which could be observed when a hint given by the facilitator or a co-participant led to the understanding of how their instrument works. Accompanied by the first realisation of what is actually played by their instrument, many participants reacted to this understanding with a facial expression of excitement or spontaneous outlouds. This could be described as a particular kind of "Aha" moment (cf. [6]), the "This is me!" experience.

A prevalent input strategy was the creation of musical patterns characterised by simple geometric properties. The most common phrases consisted of horizontal and upward or downward diagonal lines whereas in most cases all available notes were used (Figure 6). Resulting in 'closed musical figures', this approach was applied by many players providing a clear audio-visual correlation between the representation on the interface and the musical result. It appeared to us that this preference was related to the fact that for many people such figures were easier to identify in the overall musical outcome compared to more 'sparse' or complex patterns. Often such phrases were modified in an incremental manner by changing just a single event per playback cycle. This strategy suggests a systematic attempt to create distinct alterations that provide clear feedback affirming of the user's understanding of the interface.

In several cases, the similar sound characteristics of the different instruments appeared to cause difficulties for the players in identifying their pattern in the overall musical output. The reason for choosing either mallet or pitched percussion-based sounds for all instruments was motivated by the fact that these are well qualified to be transposed over a very wide pitch range having a versatile sound characteristic: It ranges from drum-like sounds in low registers to bright, bell-like sounds in high registers. This design choice aimed to enable all players to modify their phrase without restrictions over a wide

pitch range. But as a consequence, the instruments sounded quite similar when played in the same octave register. While this finding suggests that it may be better to use more diverse sounds where each is restricted to a certain pitch range, this would come at some cost, as it appeared that many players particularly enjoyed 'moving' their phrase over a wide octave range in a dynamic manner resulting in an immediate and salient acoustic feedback.

Despite the fact that the interaction with the *Polymetros* appeared to be attractive and very enjoyable for the exhibition audience, it has to be noted that collaborations involving *active engagement* between 'instrumentalists' could be rarely observed during the case study. By active engagement we refer to a situation where players coordinate their actions in a systematic way in order to develop the musical outcome over a certain period of time. However, we observed several attempts between players who commented on their actions or discussed their playing activities across the table. In all these cases the participants appeared to know each other being either friends, couples or family members.

Nevertheless, in most instances audience members who knew each other collaborated by playing together on a single instrument, rather than on multiple instruments. They were more likely to explore *Polymetros* together by explaining the interface to their companion, co-editing a musical pattern or commenting on each others' actions. These observations correlate to the findings of von Lehn, Heath and Hindmarsh [18] showing that interactive exhibits are often examined by visitors in interaction with their companions. Such co-participation on a shared instrument appeared to be a highly collaborative activity in itself.

But unlike in the pilot study, where several groups were actively 'performing' together, such attempts involving all players could not be observed during the case study. Reviewing the video material of the pilot showed that such actively coordinated collaborations mainly took place if audience members who were already acquainted approached the *Polymetros* system whilst it was not in use. In such cases it appears most likely that a group splits up to play on different instruments, explores the system together and develops strategies to coordinate their actions via verbal and non-verbal communication. In addition, this approach seems to promote mutual awareness and interest for the co-players' actions. But due to the high visitor turnout during the case study at the V&A, new players usually joined in an ongoing musical process individually rather than exploring the system together. Most of all, not knowing the other players appeared to be the main barrier to actively engage with them in order to jointly coordinate the musical outcome. Although it could be noticed that players were observing other participants' actions or discussing their own playing with their companions or members of the research team, they would not directly address their unknown co-players. However, playing techniques such as muting one's instrument rhythmically in relation to other patterns, which could be observed several times during the study, showed an explicit awareness for other players' contributions.

Beside that, the high visitor turnout during the study seemed to have a significant influence on how long the visitors stayed to play with the system: The video observations indicate that people are likely to leave their instrument if they become aware that another audience member is waiting in their direct vicinity. It appears that in such a situation many audience members feel an 'obligation to leave' in order to make room for other visitors. This is supported by the fact, that the average dwell time of 3.3 min (294 logs) approximately corresponds to the dwell time measured on the opening evening of the pilot study, where the system was similarly highly frequented (3.8 min, 92 logs). On the two following days of the pilot, which were much less well attended, the average dwell time increased to 6 min (72 logs). Along with the observation that several visitors seemed to quit playing merely because their companions were moving on, this suggests that in many cases the dwell time was determined by contextual factors rather than the participants' playing experience. This is supported by the results presented earlier indicating no association between the participants' dwell time and how they rated their playing experience in the questionnaire.

## REFLEXIONS

In the following section we reflect on the results of the study in order to evaluate our design approach and assess implications for facilitating collaborative musical experiences.

On a general level, the study indicated that the players' 'sense of control' is an important feature of a collaborative musical experience and relates to other important qualities such as the participants' overall satisfaction with their playing experience. Our approach to facilitate such a feeling of control through enabling each player to contribute on a basic musical level drawn from Minimal Music appeared to be an appropriate strategy for an interactive collaborative music system. Avoiding the use of pre-produced audio, *Polymetros* demonstrated that it is understandable and engaging for a diverse user group with different musical and technical abilities allowing all players to contribute individually to an overall musical outcome. However, the observed difficulties of several players in identifying the own contribution which was caused by the similar sounding instruments, suggest opportunities for a re-design of the sonic properties. One possibility is to implement more idiosyncratic sound characteristics for each instrument. On the other hand, such an approach has to be carefully assessed taking into consideration that it might counteract the players' individual control over their contributions by restricting the variability of their instruments' sound characteristics. However, an important feature of the system is that the sound palette can easily be changed for different contexts, for example using drum, bass and synthesiser sounds 'shifts' *Polymetros's* musical character into the realm of electronica and club music.

In contrast to screen-based interactive exhibits, which have been criticised for excluding the surrounding audience from understanding the interaction with the system by undermining "mutual and public visibility of conduct" [8], the physical interface approach showed to be an appropriate design choice for the multi-user scenario: Providing a highly visible repre-

sentation of the interaction, the design demonstrated that it succeeded in facilitating understandability for the surrounding audience while giving the participants visual access to their co-players' actions. Beside that, the physical and tactile properties of the instruments enabled more than one person to use a single instance of the user interface simultaneously - an opportunity that is often entirely disregarded by screen-based interactives [9].

As indicated by the observations, especially contextual influences such as unfamiliarity with other players and the fact that visitors mostly joined in individually rather than exploring the system as a group appeared to restrict collaborations involving active engagement between audience members. Reflecting on these findings made us aware that from a visitor's perspective 'active collaboration' might not be a necessarily relevant or desirable aspect in the context of such a highly-frequented, public setting. This corresponds to findings of von Lehn et al. indicating that it rarely occurs that exhibits in galleries or museums are jointly explored by strangers, even if these are designed to facilitate co-participation or collaboration [18]. However, it is interesting to note that, despite the limited degree of active engagements between different 'instrumentalists' during the study, half of the respondents stated in the questionnaire that they felt either fairly (34.7%) or very much (16%) connected to the other players. This indicates that many audience members experienced their playing as a joint activity.

Nevertheless, based on our experiences from the pilot study and informal evaluations we believe that active engagement among players has the potential to significantly deepen the playing experience for all participants. This raised our interest in how we can more successfully facilitate collaborations involving more active engagement while 'reducing' the observed contextual influences. We explored an intuitive strategy of facilitation within the last hours of the exhibition, when *Polymetros* was less attended. Instead of solely providing an initial guidance to each player individually, the facilitator invited all present players to explore the system together: First, group members were asked to 'wipe' the grids of their instruments in order to start a 'new composition' together. By giving instructions to the whole group the facilitator encouraged the players to contribute one after another in a round-based manner in order to successively build up the musical outcome together. This approach appeared to support mutual awareness among players by guiding their focus within the group. Moreover, it clearly illustrated 'who is playing what' and how the overall musical outcome emerges from the individual contributions of each participant. Thus, we suggest, it appeared to promote a deeper overall understanding for functionality and collaborative possibilities of the system for both players and spectators.

## FUTURE WORK

From our experiences described in the previous section, we are interested in exploring this initial group facilitation strategy in future exhibitions of the system. Furthermore, we plan to complement this approach in a more controlled study setting such as lab-based group activities in which players are encouraged to compose and perform little musical pieces together whilst manipulating features of the system to study the influence of individual control. However, as the main interest of our research lies in the support of public musical creativity, we are aware that results from a controlled study have to be carefully balanced with the findings of our field research due to the significant contextual influences as observed in the presented study. Besides, we are currently further analysing the gathered interaction data in order to characterise the musical contributions created by the participants and investigate how these relate to their responses given in the questionnaire using the matched data set.

## SUMMARY

In this paper we reported on the design and audience evaluation of a collaborative interactive music system for broad audiences. We first gave a detailed description of the design rationale in relation to relevant literature with a particular focus on how to provide novices with opportunities for musical control in collaborative contexts. The resulting design enables every player to create and control a repetitive musical pattern inspired by minimalist composing techniques aiming to support a clear identification of their playing in the collaboratively created music. The case study emphasised the importance of supporting each player's sense of control and indicated that it relates to other qualities of the participants' playing experience such as feeling satisfied with the overall interaction or feeling part of a creative process. In terms of design, the findings suggested improvements of the instruments' sound characteristics to enhance their identifiability in the overall musical outcome. We also explored an initial strategy of facilitation in order to encourage active engagement among the players.

The presented field study gave clear indications that the ways the audience approached, explored and interacted with *Polymetros* were significantly influenced by the context of the public exhibition. While the observations are specific to the case study reported in this paper, we believe that, at a more general level, they contribute to the understanding of audience interaction with collaborative interactive experiences in public settings and are relevant to inform other designs that aim to facilitate collaborative public creativity.

## ACKNOWLEDGMENTS

We would like to thank Nela Brown, Kareem Khazem, Sara Heitlinger, Richard Kelly, Colin Powell, Mark Plumbley and Irini Papadimitriou.
This work was kindly supported by the Centre for Digital Music (C4DM), Queen Mary University of London and the EPSRC funded DePIC project (EP/J017205/1), Benedikt Bengler is funded by a PhD Studentship from Queen Mary University of London.

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