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Sketching music: Exploring melodic similarity and contrast using a digital tabletop

ABSTRACT

In this article, we investigate the effectiveness of a purposely built Digital Tabletop Musical Instruments (DTMI) in helping novices and casual users to explore music composition. Our participants explored how melodic similarity and contrast can convey narrative through musical structure in sessions involving one participant and one tutor to guide the session. We structured the sessions as a combination of open-ended discussions and increasingly open-ended music-making exercises, culminating in the main task: Invent a short story and compose a melody to describe it. We found that the combination of a structured tutor-led activity and an approachable technology allowed our participants to explore the relationship between their ideas of similarity and contrast, the ways these concepts are manifested in melody, and the ways they can help describe a narrative. The hands-on activities provided adequate scaffolding for discussing the concepts and

KEYWORDS

tabletop interfaces
tangible interfaces
composition
music
narrative
similarity
contrast

contextualizing them within music. Lastly, by not requiring any formal musical or instrumental training, the DTMI allowed the participants to make music while discussing similarity and contrast in a comfortable and continuous way.

1. INTRODUCTION

Making music is too often regarded as complicated, something best left to those who are 'talented' or 'gifted'. Many tools exist that allow beginners to make music, but although these are often successful at the level of short phrases, they do not support a longer-term structure. In this article, we present a study aimed at engaging people with limited musical experience in writing original music with a sense of structure and narrative, by exploring two important concepts: melodic similarity and contrast. We aim at showing our participants that making music is an activity for anyone, given the right tools and motivation, and that engaging in it can improve their own music appreciation skills.

Claims that studying music has a positive fallout on other aspects of life are generally exaggerated, as shown by Schellenberg (2006) and Jaschke et al. (2013) among others. It is, however, noted that making music has some benefits in a wider, less academically focused sense. These include improving music appreciation skills, as well as exposure to arts and culture, which is believed to lead to long-term engagement in these cultural fields (Demorest and Morrison 2000; Foster and Marcus Jenkins 2017). With musical applications for phones and tablets, and more complex computer-based software, making music does not even require one to learn to play a traditional musical instrument anymore – although doing so can arguably improve one's discipline, empathy and self-esteem (Hallam 2010; Rabinowitch et al. 2013), as well as fine motor skills and self-awareness (Johnson et al. 2010).

In this article, we investigate how effective a bespoke digital tabletop interface (DTI) can be in supporting novices and casual users in exploring and using concepts of music composition. Our goal is to enable musically inexperienced people to explore increasingly complex musical concepts at a pace that they are comfortable with in an enjoyable, non-intimidating way. The way we enable them to do so is by letting them create their own music, playing with high-level musical notions in a simplified and encouraging environment, supported by purposely designed technology and a set of tutor-led activities. We asked our participants to make music by manipulating melodic similarity and contrast in accordance with an extra-musical narrative of their creation. This task allowed them to learn and use the notions of pitch, melodic contour, and rhythm, to compose a short piece of music with similar and contrasting parts to convey a short story.

Digital tabletops have received considerable attention over the past few decades and have been employed in a variety of applications and domains. Music is a particularly interesting domain for studying digital tabletops. On the one hand, the success of products such as the Reactable (Jordà et al. 2005), and the widespread use of touchscreen interfaces of varying sizes among musicians is a testament to the interest that such technologies generate for music applications. On the other hand, music – western music in particular – is often considered difficult to understand, appreciate and engage with by inexperienced listeners. One possible explanation for this may be found in music's inherent complexity and abstraction (Wiggins et al. 2010). This is

where touchscreens and digital tabletops can help, as they excel at representing complex, potentially abstract information in a very flexible yet concrete way (Ishii 2008). By lending physicality to an inherently aural experience such as music, digital tabletops allow users to directly manipulate music and construct a concrete connection to it, thus helping them to form mental models of music without requiring them to know how to play a traditional musical instrument.

2. AIMS

The study we present in this article is part of our attempt to answer the following overarching research question:

> How can we design a Digital Tabletop Musical Instrument (DTMI) that can support people in discussing the role of melodic similarity and contrast in suggesting narrative, and in using such concepts to compose music?

More precisely, we formulated the following subquestions.

SQ 1: What are the criteria by which the participants judge similarity and contrast in melody?

SQ 2: How do the participants understand the role of similarity and contrast in creating structure and suggesting narrative in melody? What strategies do the participants use in composing a melody that tells a story?

SQ 3: Does the DTMI provide adequate support for its users to discuss and understand similarity and contrast in melody?

SQ 4: Does the DTMI provide an enjoyable experience, favouring concentration and understanding, or does it create undue stress?

The following is a list of the forms of evidence that were considered to answer the questions just cited.

SQ 1 and 2: We took notes of the conversations between each participant and the tutor to provide evidence of how the participants developed a way of thinking about similarity and contrast. We also used application logs to have a record of all the actions performed on the DTMI, and of the melodies that they composed throughout their session, to associate with the conversation notes.

SQ 3: The tutor recorded in writing how the participants used the DTMI to compose and discuss melodies. This provided a record of the role of the DTMI as a discussion mediator.

SQ 4: We debriefed participants and asked them to fill a feedback questionnaire at the end of their sessions. In addition, the tutor noted the participants' comments and non-verbal cues throughout the sessions. The combination of these data sets

provided evidence of how enjoyable or stressful, easy or difficult the participants perceived the sessions to be.

The questions mention participants without qualifying whether they are novices or experts in music. This is a deliberate choice so that we can explore how people with different musical backgrounds respond to our study.

3. BACKGROUND

A Tangible User Interface (TUI) is a type of computer interface that allows a user to interact with digital information through physical objects representing the qualities of that information. The physical aspects of a TUI afford users not only controls for manipulating digital information but also conceptual links to it, so that the manipulation itself acquires meaning. TUIs are special purpose interfaces that are tightly coupled with the systems that they represent (Ishii 2008), and so they exist in a wide variety of forms. A DTI is a type of TUI where interaction occurs through a large, horizontal surface, and information can be manipulated by touching the surface, and placing objects on it. A DTI can often be used concurrently by multiple people, although this is not necessary.

3.1. TUIs for music

Music is a popular area of application for TUIs (Shaer and Hornecker 2010). Non-musicians often consider music difficult to engage with at a level that is more than superficial. This is possibly because the experience of music, as a listener, is mainly aural and apparently immaterial (Wiggins et al. 2010). The lack of visual and graspable dimensions may represent a barrier since we tend to navigate and interpret the environment primarily in a visual and haptic way, leaving aural dimensions to refine and improve our perception (Ekstrom 2015; Lewis et al. 2000). This is particularly relevant with beginners and casual users, where the use of concrete examples can be helpful in quickly grasping basic concepts (Atkinson et al. 2000; Shively 2015). Representing music by using visual and haptic dimensions may help some people construct mental models to think about music in ways that are more intuitively understandable and closer to individual experiences.

The hybrid approach combining the physicality of TUIs and the flexibility of Graphical User Interfaces (GUI) arguably makes digital tabletops ideally suited for applications where the amount of information is excessive (Pereda 2019), or the manipulations are too sophisticated, or both (Ishii 2008). Unsurprisingly, a large proportion of musical TUIs aimed at musicians are based on the touchscreen tablet idiom, sometimes incorporating small graspable objects, such as ROTOR (Reactable Systems 2015) based on a concept similar to that proposed by Rutter et al. (2014). DTIs present multi-layered, multi-media representations of music, and they combine it with an easily approachable interaction model. When appropriately designed, this combination can enhance the presentation of musical information to facilitate comprehension, description, sharing, and manipulation of musical objects and ideas by experienced and inexperienced users alike. Further, DTIs can lower the barrier between users of different levels of musical expertise by introducing a representation of music that is easy to read for novices, yet expressive enough for experts, such as musicians and educators.

Music in general (and western classical music in particular) can sometimes be perceived by the uninitiated as difficult to understand and engage with.

Music is, indeed, a tightly intertwined bundle of information at many different levels. For example, notes and rhythm form melodies, melodies form phrases and themes, and these can interact in more or less complex ways to create complex harmonies, moods and so on. Such complexity seems like a perfect opportunity to make good use of the flexibility and multi-media feedback capabilities of DTMIs.

Further, music is a social experience, and there is evidence that DTMIs can be a valuable platform to support collaborative music making (Laney et al. 2010) and peer learning, as well as to encourage socializing and discussing music (Xambó et al. 2013). Between the flexibility afforded by the hybrid interaction paradigm, and the natural disposition of tables to favour collaborative work (Marshall et al. 2007), it is arguable that the digital tabletop technology has the necessary qualities to support the development of valuable educational tools in general (Dillenbourg and Evans 2011) as well as in music (Xambó et al. 2017).

3.2. Enabling novices

The problem of getting novices to explore and make music cannot be tackled only by technology. It is hard to get novices to compose meaningful music, while at the same time affording them a safe playground in which they can practise and discuss musical concepts. Some novices may find it unappealing to obsess over theory and practice; instead, they may just want to play around with some music and find out how to make something they like.

In this study, we asked people to discuss and create music starting from their own extra-musical experiences. This approach is sometimes used by professional composers, where a piece of music is inspired by real-life materials such as scenes, tales and so on, sometimes with purely artistic intent, and sometimes to provide a reference for the audience to attune to the music, and better engage with it. We chose this approach to make it easier for more and less experienced participants alike to approach music making at a pace and from a direction that is comfortable for them. We chose to explore two important and complementary notions in music composition: similarity, for its value in creating structure and providing a sense of continuity and cohesiveness; and contrast, as a way of generating interest (Laney et al. 2015).

We explored a learner–tutor scenario in which a tutor guided a learner through the musical concepts by using a sequence of activities, using the DTMI where necessary. The aim was to evaluate how the DTMI could enhance an otherwise traditional learning situation, e.g. making it possible to engage in discussing music without the experience of learning an instrument or developing intermediate aural skills, and also by mediating the discussion of music between a beginner and an expert.

Despite the popularity of musical TUIs, it is surprisingly hard to find existing applications that are not only powerful and expressive, but also easily approachable by novices, and support the manipulation of musical structure. Powerful, expressive, and approachable systems do exist, but they are typically intended for live performance and improvisation – e.g. Reactable (Jordà et al. 2005), Kaossilator (Korg 2007), Tenori-On (Nishibori and Iwai 2006) – so their support for composing melody may be limited to simple and short sequences, and manipulating structure may be cumbersome. On the other hand, powerful and expressive systems that also afford flexible melody creation and structure manipulation do also exist, but they tend to be feature-rich music production software that, even when explicitly aimed at novices, may

require them to learn extra skills, or simply present many extra options that draw attention away from making. We have not found any suitable technology that fits all our needs, so we developed the bespoke DTMI that we describe in the next section.

4. A DTMI TO COMPOSE MELODY

We developed a bespoke DTMI application (Franceschini 2014a) through an iterative evaluation–improvement cycle in a series of pilot studies, including one detailed in Franceschini et al. (2014).

Figure 1a shows a screenshot of the DTMI, which is designed to be operated from anywhere around the tabletop. The design is loosely based on a timeline metaphor in which multiple short blocks, representing short melodies, can be chained and rearranged at will to form longer melodies. A block is oriented towards the user when the play button is at the top left corner. Time flows from left to right, and pitch increases upwards, as shown in Figure 2. When the play button is tapped, it changes into a stop button, and vice versa. The spatial layout is not mapped to any musical parameter other than time and pitch within individual blocks. A single, disconnected block plays in a loop until it is stopped. Blocks are chained by the white lines between them. Blocks connected in a sequence like in Figure 1a play one after the other, from left to right, before looping back to the first block. The blocks employ a piano-roll metaphor with time in the horizontal axis, and pitch on the vertical axis. The vertical axis does not necessarily map to a chromatic scale. In the example shown, a single-octave pentatonic scale is used. In fact, if we consider a block as a single 4/4 measure and a C major pentatonic scale, then Figure 1a represents the melody shown in Figure 1b.

For the study we present here, the blocks were configured to be single 4/4 measures using a C major diatonic scale, unless otherwise required by specific exercises. The stimuli used for the exercises are Figure 7 and Figure 8.

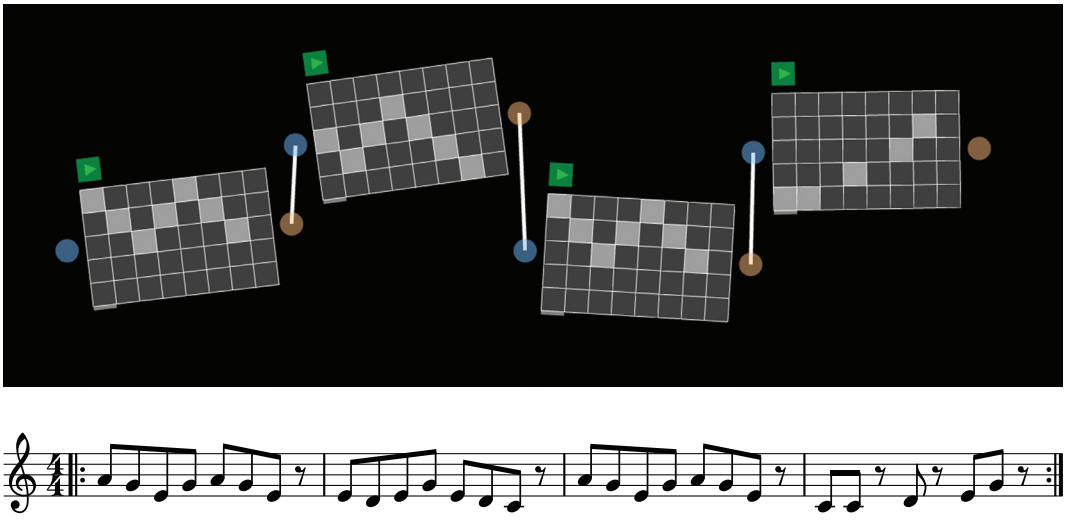

Figure 1: (a) A screenshot of the DTMI application. (b) The staff representation of the melody shown above screenshot, assuming a C major pentatonic scale between C4 and A4. © Andrea Franceschini.

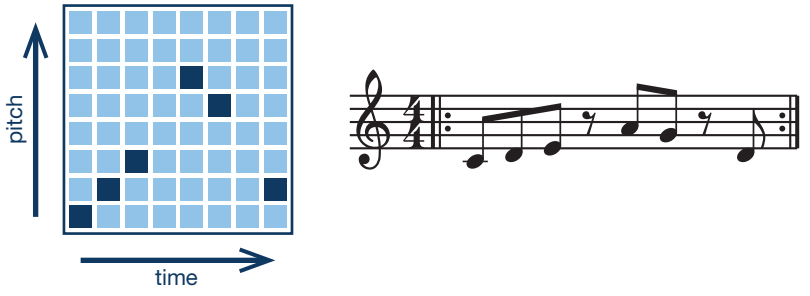

Figure 2: Left: block representation, extracted from the applications' logs, as used in the analysis. Right: staff representation of the block on the left, assuming a C major diatonic scale between C4 and C5. © Andrea Franceschini.

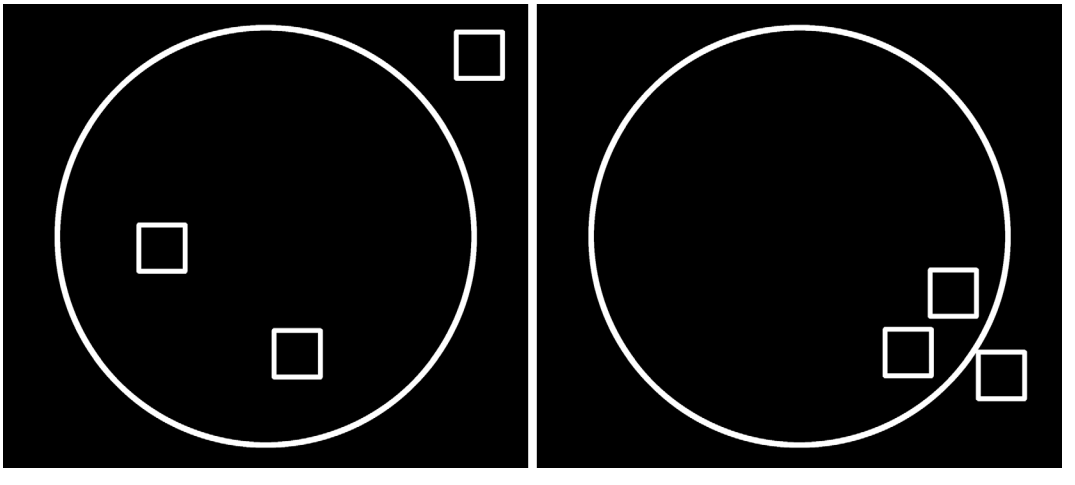

Figure 3: Examples of the listening and classification exercise. © Andrea Franceschini.

5. STUDY DESIGN

The following is an outline of the session activities. We briefed the participants on this before obtaining their written consent.

Demographics questionnaire: We asked the participants to complete a questionnaire on their musical background and their music-making experience. The questionnaire is in the appendix.

Discussion on similarity and contrast: We invited the participants to discuss similarity and contrast with the tutor in an open-ended discussion. We did this to allow the participants to explore their own understanding of similarity and contrast, and to establish a set of criteria to guide them through the rest of the session.

Listening and classification: We asked participants to use the DTMI to listen to twelve groups of three short melodies, and classify them by similarity and contrast positioning them inside and outside of a circle, as shown in Figure 3 (Franceschini 2014c). We recorded the participants' reasoning, and we engaged them in a discussion to help them develop their own ways of thinking about similarity and contrast in music. The melodies used were pre-composed, purposely manipulating one or more of a set of parameters per group – i.e. contour, rhythm, mode, expressivity – to expose participants to different types of similarities.

Challenge-response: To introduce the participants to music making by using the concepts thus far explored, we gave them seven short melodies and asked them to respond with a new similar or contrasting short melody for each of the seven. To stimulate participants to explore different strategies, increasingly strict constraints were built into the exercise, starting with a pentatonic scale in the first few presentations, moving on to two-tone and single-tone scales to force participants to consider rhythm as well as contour. The stimuli are depicted in Figure 7.

Fill-the-gaps: To help the participants develop a sense of how similarity and contrast can be used to suggest a narrative with melody, we gave them a series of short melodies, composed of three to four blocks (Figure 4), and connected in order to form a single sequence. Some of the blocks were pre-composed, and some were empty for the participants to fill in as they wished. We asked them to explain whether and why they thought their resulting composition suggested some kind of narrative. The stimuli are portrayed in Figure 8.

Storytelling: In the last exercise, we asked participants to compose a melody that, in their opinion, could convey a story, either original or pre-existing. At the end of the exercise, we asked them to explain how, in their opinion, the melody conveyed the story they chose.

Debriefing and post-session questionnaire: Lastly, we asked the participants to fill a feedback questionnaire, to assess their experience. We also offered an optional debriefing discussion for them to ask questions and provide additional feedback.

Written consent was required and obtained from all the participants. We followed the Code of Human Research Ethics published by the British Psychological Society (2014). We briefly explained the structure of the session to the participants, and we informed them of the types of data that we were going to collect, as well as their right to withdraw from participation at any point during or after their session with no adverse consequences. We explained that they could request deletion of their data up to the point of anonymity, as after that point the data could not be traced back to them. The University's Research Ethics committee approved the study as low risk.

6. METHODOLOGY

We adopted an exploratory and primarily qualitative approach for this research. We dealt with the issue of validity by collecting and analysing data from a variety of sources, including session notes, questionnaires, and application logs – and cross-validating findings to assess their credibility.

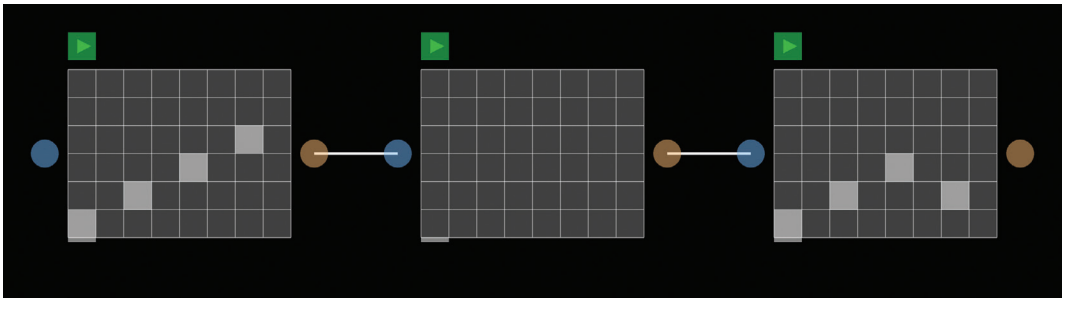

Figure 4: One of the presentations in the fill-the-gaps exercise. © Andrea Franceschini.

Please answer the following questions about your **musical experience.**

1. Have you studied music?

    ☐ I have never studied music formally or informally

    ☐ I received informal music education or I am self-taught

    ☐ I received formal music education

    - **If you have**, for how long? _____ years

2. Do you play a musical instrument?

    ☐ I play no musical instrument

    ☐ I play one musical instrument

    ☐ I play more than one musical instrument

    - **If you do**, how would you rate your skills from minimum 1 to maximum 5? _____ (consider your best instrument)

3. Have you ever composed original music?

    ☐ I have never composed original music

    ☐ I have composed original music once or twice

    ☐ I have composed original music more than a few times

    - How confident are you in your ability to compose original music? (1-5) _____

Figure 5: Demographics questionnaire. © Andrea Franceschini.

Rate the following statements depending on whether you **strongly disagree (1)** or **strongly agree (5)** with them.

	1	2	3	4	5
I felt that accomplishing the task was difficult					
I enjoyed composing a piece of music					
I concentrated intensely on the task					
I am confident in my ability to compose original music					
I think that I will compose original music in the future					

Figure 6: Feedback questionnaire. © Andrea Franceschini.

6.1. Data collection

Some of the data collection techniques we used are inspired by the work of Fencott (2012) on collaborative co-located music making, and some by the work of Xambó (2015) on collaborative tabletop music making.

Session notes were taken by the tutor during the sessions. Video recordings are often used in HCI studies, but the presence of a video camera may sometimes be intimidating to participants, especially when they are in a 'learner' role in which they may feel insecure (Broady and Duc 1995). Because of this, and because a tutor was present throughout the sessions, we decided that note taking was a better option. These notes covered the verbal discussions between participants and the tutor, as well as the participants' non-verbal cues, such as interactions with the tabletop, and other body language. We focused on actions performed on the table, the alternation between verbal and non-verbal activities, and patterns of interaction between participants and tutor (Xambó et al. 2013). The tutor, being the only person other than the participant present during the session, was also the note taker. There is the possibility that the tutor might be partially distracted from the participant while taking notes, but we considered the following two aspects. First, the notes were taken with respect to each participant's responses and actions on the tabletop, and this is no different from an interview situation. Second, using a third party note taker in the room, though certainly freeing the tutor from distractions, might have, in turn, distracted the participant and affected the one-to-one feeling of the sessions without producing significantly more useful notes than those taken by the tutor themselves.

Questionnaires were administered at the beginning and at the end of each session. We used pre-session questionnaires to assess the previous musical experience of the participants, and their self-confidence in music making. The post-session questionnaires covered the experience of the participants during the session, their feelings of accomplishment, understanding and learning, as well as their engagement and comfort. We used the pre-session questionnaires as a context for analysing the

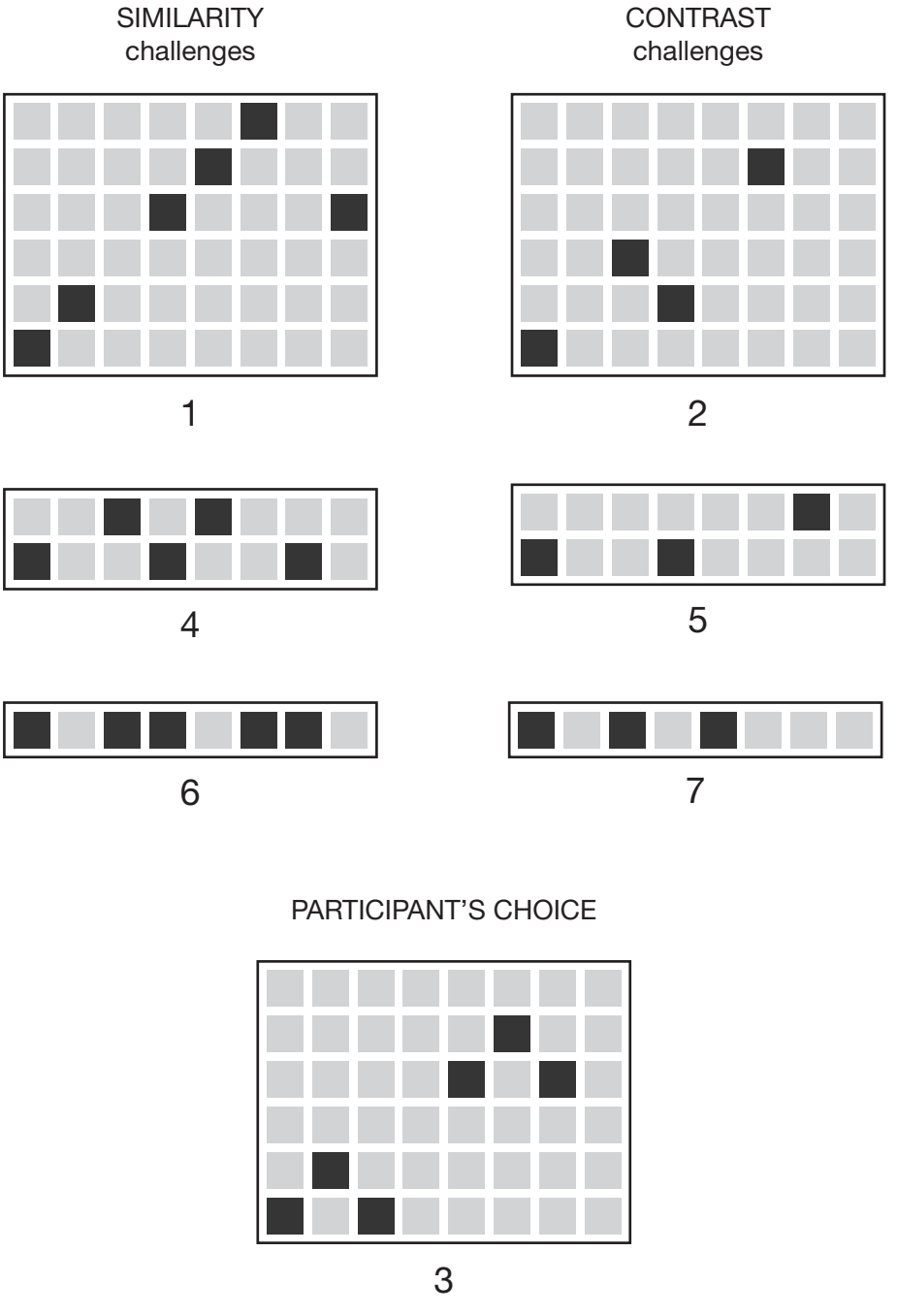

Figure 7: Stimuli for the challenge-response exercise. © Andrea Franceschini.

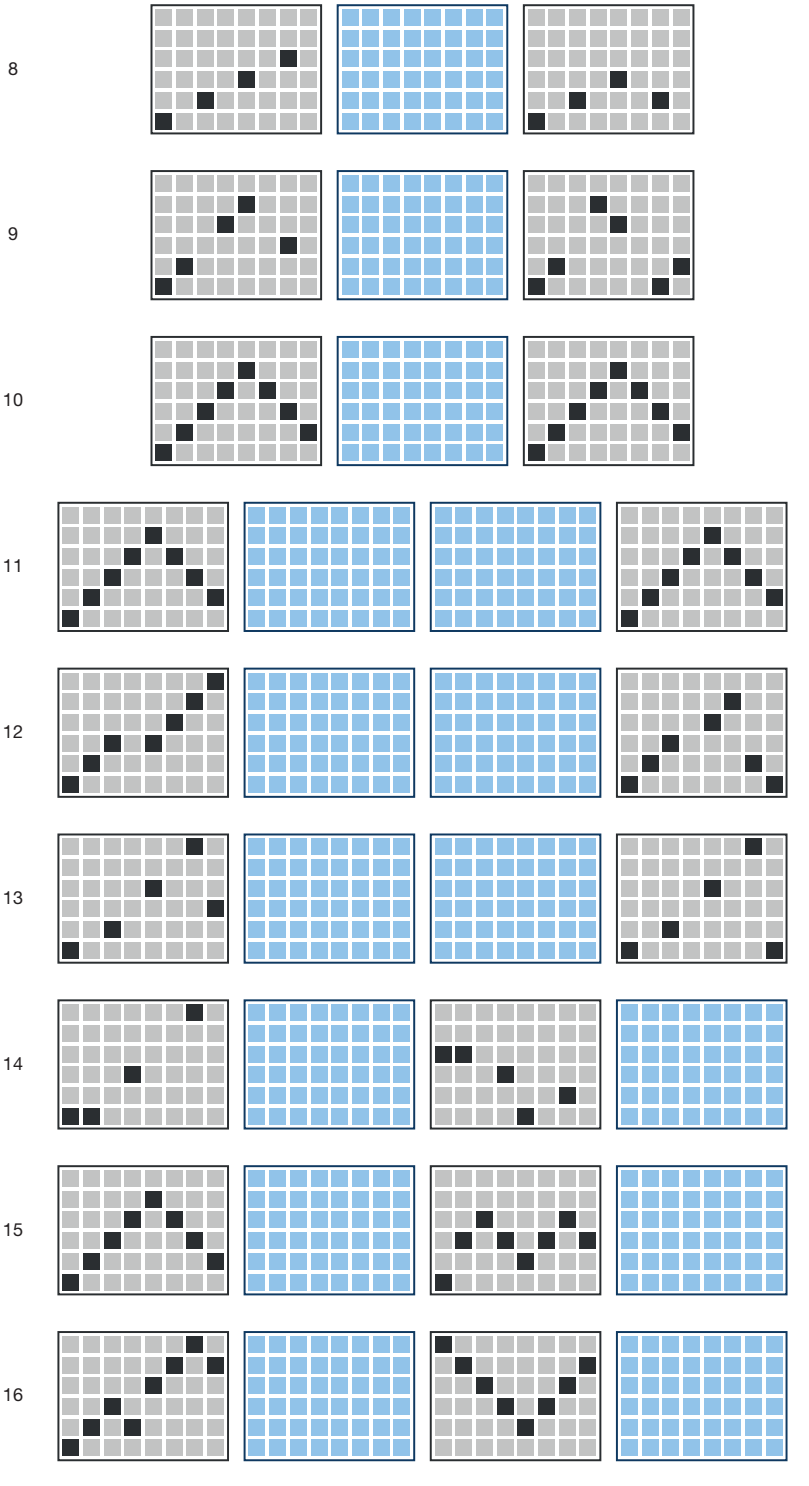

Figure 8: Stimuli for the fill-the-gaps exercise. © Andrea Franceschini.

session data, and the post-session questionnaires as insight into the participants' perception of the session, and as a form of experience evaluation. We used five-point Likert scales, which are inherently subject to some biases, including central tendency and acquiescence. We worded the statements in a strong way to mitigate central tendency bias, and to elicit a strong reaction by the participant to mitigate acquiescence. Further, we encouraged free comments to complement Likert-scale answers.

Application logs were recorded by the tabletop applications and included information such as interaction events and the music that participants composed. These logs were machine-processed to turn them into human-readable output, which was then analysed for patterns of interaction, and to provide a record of the musical artefacts to compare with the participants' explanations.

6.2. Data analysis

To understand how DTMIs can help novices to explore musical concepts, we investigated whether and how people made sense of, and used, the technology for exploring the musical concepts that we asked them to work with. This line of inquiry led to a largely exploratory study design and qualitative data analysis. We framed the music-making tasks so that there were no right or wrong answers; instead, the tasks were designed to demonstrate whether or not participants could make sense of, and use, the musical concepts, and whether the technology supported or hindered them. We applied thematic analysis (Braun and Clarke 2006) to all our data to understand the behaviour of our participants in relation to the musical and technological aspects of the study.

6.2.1. Usability analysis

The usability analysis of the DTMI was conducted by using some of the themes from the framework proposed by Hornecker and Buur (2006). This framework covers many different forms of tangible and embodied interaction, therefore we adapted them to our specific needs.

Tangible Manipulation (TM) covers the physical nature of the tangible elements that represent the information in the underlying digital system and provide a link through which this information can be manipulated. This covers how the user learns to use the DTMI by exploring its functions and using the feedback provided to navigate the musical content being manipulated.

Embodied Facilitation (EF) covers how the physical configuration of the system affects the users' ability, and leverages the users' experiences, to interact with it and manipulate the musical content.

Expressive Representation (ER) covers how the representations offered by the system convey the qualities of the digital information and allow users to use these representations to reason about it, understand it, and manipulate it in a tightly coupled way.

We analysed the participants' interactions, discussions and music in an inductive way. This means that we looked for themes emerging from the data,

as opposed to forcing the data into our pre-conceptions and expectations. The following is an explanation of the themes that emerged from the analysis.

6.2.2. Analysis of the DTMI as an exploration tool

We analysed the discussions and melodies produced during the sessions to understand how the DTMI could support the discussion of musical concepts between its users and a tutor (SQ 3). In doing so, we only used the themes Tangible Manipulation (TM) and Expressive Representation (ER) in this analysis. The theme Embodied Facilitation (EF) was not considered useful for this part of the analysis, as it provided no additional information than that gathered from the usability analysis.

6.2.3. Analysis of the use of similarity and contrast

We decided to use two additional themes to analyse the discussions and melodies produced. We used these themes to organize the data in relation to the evidence needed, as explained in Section 2.

- **Development of criteria for similarity and contrast**, to see how participants developed ways of thinking about melody in terms of similarity and contrast. In particular, two subthemes emerged from the transcripts: the idea that **similarity is not identity**, but a nuanced property that depends on a variety of aspects; and the necessity for **comparability and relatedness** to produce meaningful comparisons, particularly to determine contrast.
- **Use of criteria for similarity and contrast in suggesting narrative**, to see whether and how participants worked with melody to express narrative by using the criteria they had previously developed. Four criteria emerged from the data, thus we used these as themes to organize the analysis. These were: the **use of mood**, particularly to identify contrasting moments; the **use of melodic motifs** to mark different aspects of the narrative; the **visual representation of music**, in working with both similarity and contrast; and the **use of variations of a motif**, to suggest an evolution in a particular aspect of the narrative.

7. FINDINGS

Twenty-four participants volunteered for the study. Excluding the initial discussion and the final debriefing, the sessions lasted approximately between 50 and 128 minutes (mean = 81′ 33″, sd = 21′ 14″).

7.1. Demographics and feedback

Table 1 summarizes the demographic data collected with the pre-session questionnaire. We found that fifteen participants had studied music for fewer than two years, often in secondary school, so we decided to consider them inexperienced. Most participants reported being not very confident in their potential musical abilities, with inexperienced participants being slightly more confident than experienced participants.

Table 2 summarizes the feedback data collected with the post-session questionnaire. The participants found the tasks reasonably easy (Q4). Twelve participants concentrated intensely on the tasks (Q6), and nineteen

(a) Q1: Have you studied music?				(b) Q2: Do you play a musical instrument?		
No		**Informally**	**Formally**	**No**	**One**	**More**
Beginners	**9**	5	1	**10**	2	3
Non-beginners	0	1	**8**	2	3	**4**
Total	**9**	6	**9**	**12**	5	7

(c) Q3: Have you ever composed original music?				(d) Q2.1: How would you rate your skills on your best instrument?					(e) Q3.1: How confident are you in your ability to compose original music?				
Never		**Occasionally**	**Often**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Beginners	**13**	1	1	0	**4**	1	0	0	**6**	6	3	0	0
Non-beginners	**7**	2	0	1	3	2	1	0	**5**	4	0	0	0
Total	**20**	3	1	1	7	3	1	0	**11**	10	3	0	0

Table 1: Summary of the answers to the demographics questionnaire.

participants enjoyed composing a piece of music (Q5). During the debriefing, many described the tasks as 'challenging' and 'not always intuitive'. This does not necessarily contradict the answers to Q4: the tasks were perceived as reasonably easy to perform but not trivial, thus suggesting that the design of the exercises provided a balance between challenge and enjoyment. Of the 21 participants who said they were not very confident in their musical abilities (Q3.1), eighteen said they were at least somewhat likely to try to make music again in the future, and twelve of these were very likely to. The general increase in confidence and the positive outlook on the possibility of trying to make original music in the future suggest that combining a simplified, playful musical interface with appropriately designed exercises can provide a challenging and motivating experience that encourages people in engaging with music, and learning more about it (SQ 4).

7.2. Usability

The usability of the two applications developed for this study was only briefly assessed. The application used for the *listening and classification* task had very minimal functionality and was only used for a small part of the session, therefore we deemed a full usability analysis unnecessary. The application used in the music-making tasks was more thoroughly assessed in a previous study (Franceschini et al. 2014), therefore here we summarize previous findings and note any additional insights that emerged during this study.

> **Listening and classification:** The size and placement of the touchscreen allowed all participants to comfortably reach the three icons with their hands, and to drag them anywhere on the screen. Two participants chose to sit next to the screen, instead of standing up like most participants, with no adverse effect. We offered to all the participants a full, verbal explanation of the interface, and we encouraged them to perform the actions by themselves. All the participants were able to use the interface after performing just a few actions. This is evidence that the

(a) Q4: I felt that accomplishing the task was difficult					
	1	**2**	**3**	4	**5**
Beginners	1	**7**	3	4	0
Non-beginners	**3**	2	2	1	1
Total	4	**9**	5	5	1

(b) Q5: I enjoyed making music					
	1	**2**	**3**	**4**	**5**
Beginners	1	0	4	2	**8**
Non-beginners	0	0	0	**6**	3
Total	1	0	4	8	**11**

(c) Q6: I concentrated intensely on the task					
	1	**2**	**3**	**4**	**5**
Beginners	1	1	3	3	**7**
Non-beginners	0	1	2	1	**5**
Total	1	2	5	4	**12**

(d) Q7: I am confident in my ability to make original music					
	1	2	3	4	5
Beginners	2	3	**7**	2	1
Non-beginners	1	**4**	3	1	0
Total	3	7	**10**	3	1

(e) Q8: I think that I will make original music in the future					
	1	2	3	4	5
Beginners	1	**6**	3	3	2
Non-beginners	2	1	**3**	**3**	0
Total	3	**7**	6	6	2

Table 2: Summary of the answers to the feedback questionnaire.

interface provided *lightweight interaction* (TM) – i.e. it could be learned through small, experimental steps – and that it gave immediate feedback after the users' actions.

Music composition: Findings from the previous assessment (Franceschini et al. 2014) were largely confirmed. In particular, the interface invited immediate interaction from the participants. Three participants took some time to explicitly learn the interface by asking questions, whereas the rest started working on the tasks immediately, learning how to use the interface as they worked. This is evidence that, for the vast majority of our participants, the interface provided *lightweight interaction* (TM). Regardless of how they approached learning the interface, the participants were all able to use the interface to perform the music-making tasks, evidence that the DTMI provides sufficient *isomorphic effect* (TM) – i.e. it is easy to understand the relationship between actions and their effects – and clear *access points* (EF) to participants, so that its users can quickly identify the relevant affordances, and understand how to use them. Lastly, the application was designed to support gestures commonly associated with touchscreens, such as dragging, pinching and scribbling. All the participants intuitively understood how to use these gestures and their musical effects, and this is evidence that the DTMI provided a *tailored representation* (ER) of music, building on the participants' experience and behaving in a familiar way.

Because participants in the previous study struggled with connecting blocks into sequences, we made the connection handles approximately 50 per cent larger in the hope of making this action easier to perform. Application logs confirmed that this resulted in a much lower failure rate compared with the logs recorded in our previous study (Franceschini et al. 2014).

In summary, both applications presented very few usability challenges (SQ 3), and no participant made significantly negative comments on the interface. Two, however, wished that the blocks allowed polyphony.

(a)		(b)	
Group	**Parameters**	Criteria for **similarity**	Criteria for **difference**
1	**Contour** (intervals)	Contour	Contour
2	**Mode, contour**	Contour	Contour
3	**Rhythm, expressivity** (legato, staccato)	Expressivity	Expressivity, rhythm
4	**Contour, expressivity** (legato, staccato)	Contour	Expressivity
5	**Mode**, contour	Contour	Contour, mode
6	**Mode, rhythm** (syncopated)	Mode (over rhythm)	Mode, rhythm
7	**Contour, rhythm** (straight vs. shuffle)	Contour, recognizability	Recognizability
8	**Contour, expressivity** (dynamics)	Contour	Expressivity
9	**Mode, contour**	Recognizability	Recognizability
10	**Mode, expressivity**	Mode	Expressivity, mode
11	**Mode, rhythm** (syncopated)	Mode, rhythm	Mode, rhythm
12	**Contour**	Recognizability	Rhythm

Table 3: (a) List of parameters that were manipulated in composing the melodies in the listening and classification *exercise; (b) Corresponding criteria identified by the participants.*

7.3. Thematic analysis

The following is a summary of the analysis of the sessions in terms of their musical content and outcome. For reference, we present the data set collected for the three cases examined in Section 7.4 (Franceschini 2014b). In the block diagrams, user input is in blue. A full, in-depth analysis is available in Franceschini (2016).

Development of criteria for similarity and contrast: The tutor initially engaged the participants in a discussion of the concepts of similarity and contrast in non-musical terms. The tutor encouraged them to discuss the concepts freely, and to develop a set of criteria that they could use to evaluate similarity and contrast in real-life situations. The following two ideas emerged prominently across the sessions:

- **Similarity is not identity**: Participants often tried to characterize similarity in terms of identity, but soon realized that this was not sufficient, as similar things could be similar in certain aspects, and not in others. From this idea emerged the notion of similarity as a multi-dimensional property, meaning that objects can be similar in many aspects – e.g. chairs have analogous shapes, and the same function, but can be made of different materials – or in very few aspects – e.g. elephants and frogs are animals who both feed and breathe, but differently, and are radically different in many other aspects such as size, colour, shape, motion and so on.
- **Comparability needs relatedness**: The notion of multi-dimensionality prompted questions regarding when and how different objects are reasonably comparable. For example, one could argue that it is more reasonable to compare chairs with chairs than elephants with flies. A similar line of reasoning resulted in the notion of *meaningful*

> *comparison*, or: when does it make sense to compare two objects? What and how many dimensions do we need to be able to compare these objects with to decide whether they are similar, contrasting or simply different?

The participants then discussed how the criteria they had identified mapped to musical criteria. This process was aided by the *listening and classification* task. Table 3a lists the parameters that were manipulated to compose the groups of three melodies to be used in this task. The main results of this task were (1) that the participants could map at least some of their initial criteria onto musical criteria, as they worked on the classification task, and (2) that it was not always clear to participants whether one of the three melodies could be classified as contrasting with the other two; however, they could always find one of the melodies that was 'different' from the other two. Table 3b shows the criteria that participants used when classifying the melodies in each group. It was not very surprising that contour was used predominantly when evaluating similarity, as this is a prominent criterion in the literature (Eerola et al. 2001; Urbano et al. 2011). Criteria for difference and contrast were much less clear: participants could only express these in terms of how the melodies made them feel – e.g., feeling 'happy', 'creeped out', 'weird', 'odd' and so on. Participants also mentioned expressivity, often opposing human and mechanical performance.

To reinforce and test these criteria, participants completed the two music-making tasks described in Section 5: *challenge-response*, and *fill-the-gaps*. The first task was designed to let the participants practise their criteria in a more autonomous way. The role of the tutor was limited to advancing the presentations on the interface, instructing that the response be similar or contrasting, and to observe and record the participants' working and explanations. The second task was designed to let the participants choose autonomously how they wanted to complete a partly composed melody, so that they could better understand how similarity and contrast can be used to compose longer, more complex melodies. The role of the tutor was to advance the presentations, to encourage the participants to think how the melodies could convey a short story and to observe and record the participants' working and explanations.

The main finding was that the participants reacted positively to the challenge of working more and more autonomously but struggled with explaining their work. In particular, although they could describe which of the criteria they used, they could not always explain why they did so, and often cited 'gut feelings' and the melody sounding 'right', or better than various alternatives they tried. In the *fill-the-gaps* exercise, participants felt more confident in their working, and they sometimes provided a narrative description of their work, however simplistic.

Use of criteria for similarity and contrast in suggesting narrative: Twenty-one participants completed the final storytelling exercise, whereas three had to interrupt their sessions for a variety of reasons. Of these 21 participants, only fourteen provided a story to go with the melody, therefore only these were considered in the analysis of this exercise. Examples of the stories provided include a squirrel fetching and hiding an acorn, the entrance of someone majestic and more personal narratives such as a commute home, a participant's child waking up in the morning, and so on. This is an encouraging result because it shows that, within 20–30 minutes of focused discussion, and using a purposely designed interface that simplifies melody without

trivializing it, mostly musically inexperienced people managed to respond to rather non-trivial music composition challenges. This covers subquestions 1 (development of criteria), 2 (use of said criteria to compose melody) and 3 (DTMI support).

7.4. Analysis of the storytelling exercise

We encouraged the participants not only to create a general feeling for the story with their music, but also to create different sections related to different parts of their stories. Not all the 21 participants produced melodies that incorporated this suggestion, nor were they always able to explain which part of the melodies related to which part of their story. However, the fourteen who did did so in a clear and convincing way. Analysis of the individual sessions revealed that the participants who did show high engagement through the entire session, and, save for one, reported being likely to try to make original music in the future. We present here three examples of the melodies that were produced by the fourteen participants who provided a story to go with their melodies. We chose three examples that we think are notable in terms of articulation and mapping between the story and the corresponding melody, as well as for their use of similarity and contrast.

Example 1: 'building up anticipation for a big event, which blows up and there is disappointment' – The participant indicated that the continuously rising melody in the first four blocks represented anticipation building up as the event approaches. The last three blocks instead represent the sense of disbelief (block 5) and discontent (blocks 6 and 7) when the event failed to live up to the expectations. The melody is clearly divided in two parts, in which block 5 represents a tense moment separating the first part, with a positive outlook, from the second part, with a negative outlook.

Example 2: 'slow majestic entrance of an important person among a silent crowd, then people explode in cheers, then the person sits and makes everyone quiet' – the participant indicated the blocks on the DTMI while describing the mapping between the melody and the story. The first four blocks represent the majestic entrance of the important person – 'perhaps a king or a high dignitary' – and their slow walk across the room, among the silent crowd. The fourth block was indicated as the moment when the important person reached their destination and turned around towards the crowd. Blocks 5 and 6 were mapped to the moment when the people 'explode in cheers', and blocks 7 and 8 were indicated as the moment when the person 'sits and makes everyone quiet'. The strategy was to compose different themes for different moments in the story. In particular, the participant explained looking for a 'monotonous, yet uplifting feeling' for the majestic walk, and 'a more exciting and random melody' for the cheering part, 'and then back to the important guy' with the last two blocks.

Example 3: 'this is the story of my son who wakes up every morning, then comes wake me up' – the participant explained that she composed the blocks based on her level of awareness that her son is awake at any moment. In this light, the participant mapped the first two blocks to the son quietly moving in his bed (block 1) and stepping down from it (block 2). The third block was mapped to the son entering the parents' bedroom and shaking the mother until she wakes up. Block 4 was described as 'my realisation that I have to leave the bed', and block 5 was 'us going downstairs to make breakfast'. The participant explained that she mapped not only the height of the notes to her level of awareness, but also the number of the notes, indicating that more

Participant	Strategies
1	Themes, variations
2	Themes
6	Mood
7	Mood
12	Mood, themes
14	Visual
15	Mood, themes
16	Mood
17	Variations
19	Mood, visual
20	Themes
21	Mood
23	Themes
24	Mood
(a)	

Strategy	Count
Mood	8
Themes	6
Variations	2
Visual	2
(b)	

Table 4a and b: Summary of the music composition strategies used by the participants.

notes and fewer pauses meant increased awareness. However, the last block was explicitly described as 'not that I'm less aware of it, it's just we go downstairs', implying that, in that block, she also used contour to describe the scene visually.

In summary: The analysis of the remaining storytelling exercises is provided in Franceschini (2016). Of the fourteen participants included in the analysis, nine were considered beginners, and five non-beginners, and they all declared that they had never composed music earlier. One non-beginner reported not being more likely than before to try to compose original music in the future, whereas all nine beginners, and four of the non-beginners, reported being more likely than before by one point on a five-level scale. This would suggest that the session may have had some impact on their self-confidence, by providing them with an easily approachable way of making music (SQ 3 and 4).

The strategies adopted by the participants (SQ 1 and 2) were classified into four categories:

- **mood**: mapping the evolution of the mood to musical parameters;
- **themes**: associating different themes to different parts of the story;
- **visual**: drawing shapes reminiscent of the events in the story;
- **variations**: applying variations to otherwise repetitive patterns.

Table 4a summarizes the strategies used by the fourteen participants that were included in the analysis of the storytelling exercise. Table 4b summarizes how many times these strategies were used by the fourteen participants. The sum exceeds the number of melodies that were analysed, because some participants used multiple strategies.

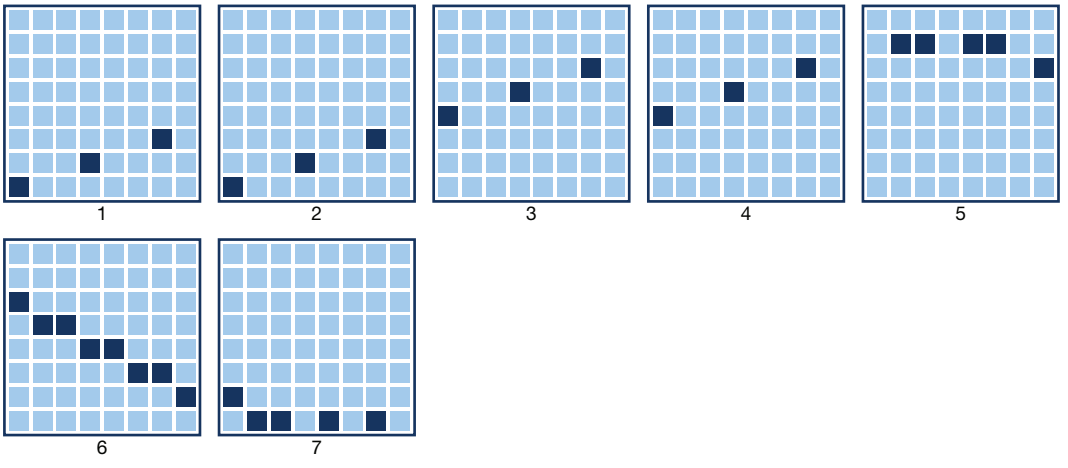

Figure 9: Stimuli for the fill-the-gaps exercise. © Andrea Franceschini.

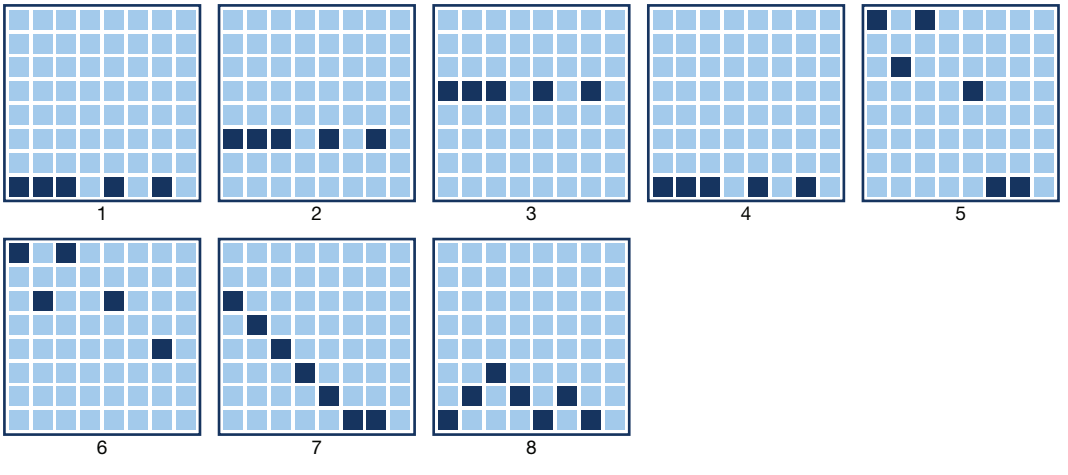

Figure 10: Stimuli for the fill-the-gaps exercise. © Andrea Franceschini.

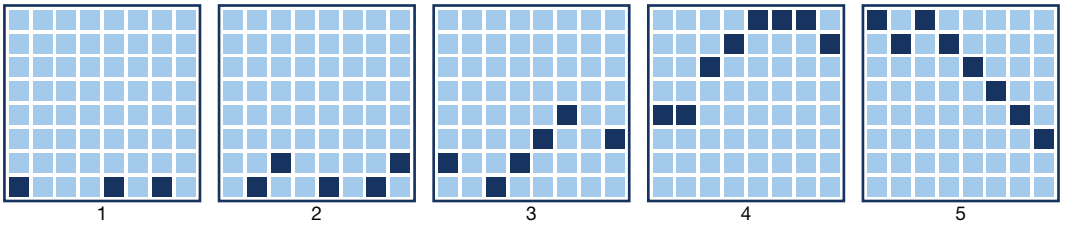

Figure 11: Stimuli for the fill-the-gaps exercise. © Andrea Franceschini.

8. DISCUSSION

The goal of this study was to understand how a purposely designed DTMI could support and facilitate musically inexperienced users in the exploration of non-trivial musical concepts.

8.1. Summary of the findings

First, we found that the DTMI was successful from a usability point of view, and provided adequate support and scaffolding for the participants to explore music in a friendly, hands-on way (SQ 3, Section 7.2). The data collected during the sessions suggest that being able to manipulate music in a playful, informal way helped participants to discuss and reason about music without first having to learn and use a more traditional musical instrument. Most importantly, the feedback provided by the participants indicated that they felt encouraged by the challenges (SQ 3 and 4, Section 7.1).

Second, the support and structure provided by the human tutor guiding the session arguably helped the participants to direct their exploration of the musical concepts (SQ 1 and 2, Section 7.3). Some participants found it relatively easy to engage in a discussion over an unfamiliar topic, whereas others required prompts and encouragement from the tutor to progress. Overall, we think that the tutor's ability to adapt and direct was essential to explore the unfamiliar material effectively.

Third, this study provided evidence that the participants developed ways of thinking about melodic similarity and contrast, and that they identified several criteria for melodic similarity, difference and contrast (SQ 1, Section 7.3). Further, a large portion of the participants successfully used these concepts to compose and describe a melody that conveyed their chosen narrative (SQ 2, Section 7.4).

8.2. Limitations

We recognize two problematic aspects in our study. First, 24 participants constitute a relatively small cohort. This afforded us the ability to drill down into the musical aspects of the sessions, and explore issues arising, paying a limited cost in time and resources. At the same time, having such a small cohort of essentially self-selected volunteers means that we might have obtained a non-representative sample in terms of musical experience and interest in music. We considered this limitation when analysing the demographics data (Section 7.1) and found that most participants had some prior musical experience, as many different school systems include some level of music education. However, we concluded that such a level is basic enough to classify these participants as beginners. We do recognize that, lacking some form of aptitude testing or graded assessment, we are grouping together participants of varying musical ability. However, we considered that introducing such assessment into our sessions would have unnecessarily complicated the sessions without adding significantly useful information. We did, instead, use years of musical education and experience as a rough proxy measure.

Second, although the study allowed us to gain considerable insight into the individuals' understanding of the notions, and composition practice (SQ 1 and 2), we could not perform a longitudinal study to track the progress of individuals through time, as well as across different musical concepts. To mitigate this, we would need the support structure that an institution such as a

school could provide, with the additional benefit of access to a formal progress evaluation framework.

8.3. Lessons learned

Our participants worked effectively with similarity and contrast to produce original and structured music. Nearly all the participants came out of the studies confident that making music is something that they can do, even if not in an expert way, given the right tools and motivation, rather than a specialized activity from which they are excluded. Opinions on this varied, depending on the level of musical experience. Participants with some experience were generally satisfied with their work, and those with less experience were happy that they could make some music at all. Participants also appreciated the constraints designed into the studies, which confirmed the fitness of these constraints to allow people to focus on the music-making aspects by providing a simple, streamlined and easy to learn combination of interface and activities.

In designing our study, we had to decide how to introduce our participants to music making. We knew that we wanted participants to make not just music but also music with a sense of structure. We had some previous success working with melodic contours (Franceschini et al. 2014), so we decided to explore melodic similarity and contrast, two music composition concepts that are important to give a sense of structure to music, yet sufficiently easy to grasp, especially in relation to non-musical material. The literature on similarity and contrast very rarely mentions narrative, but rather focuses more on the notions of structure, and musical form. However, contrast is often used to create tension and resolution between parts. Thus, narrative, with its inherent structure, expressed in terms of similarity and contrast, was an interesting topic for participants to explore. We also considered what type of activities would be useful to introduce our participants to the use of similarity and contrast in melody composition. Educational software often times takes an instructionist approach, which presents notions and quizzes to the learner, and merely tests notion retention. However, we think that this is not a useful approach when the goal is to have someone create something new. We, therefore, adopted a more constructivist, hands-on approach that encourages participants to get their hands dirty and build something by themselves. We believe that this approach worked very well in terms of building up confidence in the participants and enabling them to experiment with music making.

8.4. Future research

This study focused on one-to-one interaction between a tutor and a learner. Exchange of knowledge happened mostly around the DTMI, with some instances of both tutor and learner sharing the DTMI. In essence, the transfer of knowledge was largely one way, from the tutor to the learner, as it would be in a similar real-world situation. There is, however, evidence of knowledge transfer between peers in undirected collaborative scenarios with groups of participants of varying levels of expertise. In such a scenario, participants share their knowledge with each other, and contribute to produce new knowledge within the group while working together, thus discovering and learning new features of the system and possibly acquiring new musical knowledge, all while producing a musical piece or performance (Fencott 2012; Xambó et al. 2013). We are planning a follow-up publication that will explore group interaction and peer learning.

9. CONCLUSION

Music is complicated, and it is hard to argue that technology alone can simplify it. The DTMI that we developed, combined with the set of activities that we designed around it, proved to be adequate in supporting the exploration of melody by musically inexperienced people. In particular, the DTMI proposed a simplified representation of melody that transformed an arguably complex and intimidating entity into something that could be easily manipulated without requiring extensive specialist knowledge. We designed the activities around the notions of melodic similarity and contrast as ways to achieve melodic structure, and we engaged our participants in composing melody to tell a story. As a consequence, both musical novices and more experienced musicians were able to discuss music at a level that they were all comfortable with, to explore the musical concepts that we proposed, and to compose simple pieces of music by using similarity and contrast to express structure and some form of narrative. In fact, in nearly all the cases, the participants came out of the studies knowing that making music is not precluded from them, but instead that it is something that they can do, even if not in an expert way, given the right tools and motivation.

We think that the findings presented in this article point to the need for incorporating conceptual tools and educational practice in designing technology that aims at facilitating engagement with music. In fact, since music is a complex, multi-faceted, multi-layered phenomenon, we argued that the flexibility of DTIs may be in an ideal position with respect to this aim. Our design approach can be adapted to other similarly complex areas of knowledge. However, one should always be wary that increasing complexity can lead to increased fragility and cognitive overload: it is a difficult balancing act, and one in which the synergy between domain experts and interface designers is invaluable.

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