ANDREA FRANCESCHINI
University of Cambridge

ROBIN LANEY
The Open University

Sketching music together: Mixed groups exploring melodic similarity and contrast using a digital tabletop

ABSTRACT

In this article, we investigate whether and how a purposely built digital table-top musical instrument (DTMI) can help groups of novices and casual users to explore music composition. Working together in small groups around the DTMI, our participants explored how the musical concepts of melodic similarity and contrast can convey narrative through musical structure. We build on our previous work that investigated a one-to-one learner–tutor scenario and expanded it to groups of peers. Similarly to our previous study, we adopted an exploratory and primarily qualitative approach, involving 24 participants divided into eight groups of three each, sampled from the general population via flyers and word of mouth. We structured the sessions as a series of open-ended discussions of the notions of similarity and contrast, starting from a general point of view, leading up to the task of inventing a short story and composing a melody to describe it. Although the two studies may appear superficially similar, the group element

represents a fundamental difference, as we found. The combination of technology and group setting was instrumental in helping less experienced participants discuss music with more experienced participants by using a simplified yet expressive representation of music that could be used to discuss complex aspects of melody and composition.

1. INTRODUCTION

Novices often take to making music quickly, yet just as often they can feel unprepared to make music in a group. Stepping into a group of people we perceive as more expert than ourselves can be energizing, but can also feel intimidating. Yet, making music in a group is an activity that many enjoy and benefit from across a diverse range of aspects and demographics – that is, senior citizens (Creech et al. 2013; Hallam and Creech 2016; Hallam et al. 2012), mental health patients (Perkins et al. 2016) and, more generally, young students and adults from different walks of life (Kokotsaki and Hallam 2011; Weinberg and Joseph 2017; Williamson and Bonshor 2019). There can be many reasons why one feels unprepared to join a music-making group: for example, perceived lack of instrumental skills or lack of ability to quickly understand music and go along with the rest of the group. Musical applications and games make it easier than ever to promote music-making, however casual and simplified (Franceschini et al. 2020), and, therefore, it is increasingly important to study ways of doing this in a positive and meaningful way.

In this article, we present a study aimed at engaging small groups of people of mixed musical experience in writing original music with a sense of structure and narrative by exploring two important concepts: melodic similarity and contrast. We have previously developed and tested a *Digital Tabletop Musical Interface* (DTMI) that facilitates the creation, manipulation and discussion of melody (Franceschini et al. 2014, 2020). We aim to show to 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. We also aim to investigate whether mixing people with different levels of musical experience facilitates the least experienced in discussing music, and the more experienced in expanding their understanding and use of the notions.

In a previous study (Franceschini et al. 2020), we found that participants engaging in one-to-one tutor-led sessions were able to explore some key musical concepts and use them to produce a short piece of music with narrative intent. We also found that our DTMI provided a powerful transformational representation of music, allowing our participants easy access to music-making. Furthermore, the DTMI helped our participants to focus their exploration and record their decisions and thought processes. However, digital tabletops are naturally multi-user platforms. Existing research shows how users can collaborate with peers of varying levels of musical expertise to exchange, refine and build up their musical knowledge around a DTMI over time (Xambó 2015).

In this article, we investigate how effective a bespoke digital tabletop interface can be in supporting groups of such users in exploring and using concepts of music composition. Our goal is to enable musically inexperienced people to explore fundamental musical concepts in collaboration with more experienced musicians in an enjoyable, non-intimidating way. We asked

groups of participants of mixed musical experience to use melodic similarity and contrast to compose a melody that, in their opinion, helped tell a short story of their creation, an approach sometimes used by professional composers drawing inspiration from real-life materials such as scenes, tales and so on. This task allowed them to reflect on the notions of pitch, melodic contour and rhythm and to compose a short piece of music with similar and contrasting parts to convey a short story.

Multi-modal, multi-user digital interfaces have received considerable attention over the past few decades and have been employed in a variety of domains. Music is a particularly interesting domain for studying digital tabletops. On the one hand, the widespread use of touch-screen and tangible interfaces of varying sizes among musicians is a testament to the interest that such technologies generate for music. On the other hand, music is often considered difficult to understand, appreciate and engage with by inexperienced listeners, possibly, but not exclusively, because of music's inherent complexity and abstraction (Wiggins et al. 2010). Touch-screens and digital tabletops not only excel at representing complex and abstract information in a concrete and familiar way (Ishii 2008) but also, particularly in the case of tabletops, naturally invite multiple people to work together. Concrete and familiar representations make it easier to construct mental models of music, and natural around-the-table collaboration makes it easier to share and discuss such mental models with others, thus helping to explore music without necessarily requiring traditional instrumental practice, which some can find a barrier.

2. AIMS

In this article, we report on a study that is part of our attempt to answer the following overarching research question: How can we design a 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?

In a previous article, we addressed the same research question focusing on individuals in a tutor–learner scenario (Franceschini et al. 2020). In this article, we recontextualize our previous work in a group setting, and we attempt to answer the following sub-questions.

SQ1.   What are the criteria by which the participants judge similarity and contrast in melody?

SQ2.   How do the participants understand the role of similarity and contrast in creating structure and suggesting narrative in melody? What strategies do they use in composing a melody that tells a story?

SQ3.   How do the participants use the DTMI as a mediator for discussing melodic similarity and contrast?

SQ4.   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 we considered to answer the questions above.

- SQ1 and 2: We video-recorded each session entirely, from the initial group discussion on similarity and contrast to the final explanations that the groups provided regarding melodies and narratives that they composed. The conversations provided insights into how the participants

understood similarity and contrast and how they used them in relation to music.

- SQ3: The video recordings also provided evidence of how the participants interacted with each other, and with the DTMI, and of how they used the DTMI as a discussion mediator and as a record of their discussion and decisions. Application logs provided a formal record of the actions performed on the DTMI and of the music produced during the sessions. This provided a record of the role of the DTMI as a discussion mediator.
- SQ4: We debriefed participants and asked them to fill an extensive feedback questionnaire at the end of their sessions. In addition, annotations of instances of non-verbal communication recorded in the videos – for example, embodied interaction, movement around the DTMI, gesturing – contributed to understanding whether or not the participants enjoyed their sessions. The combination of these datasets 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 the interactions and cooperation between people with different musical backgrounds in relation to discussing and using the musical concepts to compose music with intent.

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 to give meaning to the manipulation. TUIs are special-purpose interfaces that are tightly coupled with the systems they represent (Ishii 2008). Because of their special-purpose nature, TUIs exist in a wide variety of shapes and forms. A digital tabletop interface (DTI) is a type of TUI where interaction occurs through a large, horizontal surface where information is presented, explored and manipulated through touch and objects placed on the surface. A DTI can often be used concurrently by multiple people, although this is not necessary. Examples of collaborative musical digital instruments include mouse-and-keyboard systems such as jam2jam (Dillon 2006) and the work of Fencott (2012) on co-located collaborative music-making as well as the DTMI Reactable (Jordà et al. 2005). For a more complete review of the use of TUIs in music, see Franceschini (2016) and Franceschini et al. (2020).

The problem of getting novices to explore and make music cannot be tackled only with 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. Technology-aided group music composition has been studied in the past with both children (Charissi and Rinta 2014; Hogenes et al. 2016) and adults (Biasutti 2015; Habron et al. 2013), and the results are encouraging in terms of fostering collaboration and a sense of personal growth and achievement and encouraging continued engagement in music-making. Two aspects often

occur in these studies: (1) structured activities work best with music-making novices, and (2) technology can get in the way of the creative process unless it is designed with specific creative goals in mind.

In our previous study, we set up one-to-one tutor-led sessions in which participants discussed musical concepts with a tutor around a DTMI and went through a series of increasingly complex exercises using the DTMI, culminating in an open-ended composition task (Franceschini et al. 2020). The musical concepts discussed were melodic similarity and contrast and how to use them to compose melody using a narrative as extra-musical reference and inspiration. We found that the device of composing a piece of music according to a chosen narrative worked well to focus the mind of people with very little musical experience and to help them achieve insights into the musical concepts discussed in their sessions. We chose to explore the role of melodic similarity and contrast in suggesting a narrative, as this is sometimes used by professional composers, where a piece of music is inspired by real-life material 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.

In the study we present in this article, we set up a cooperative scenario in which peers of mixed musical experience worked together towards a music composition goal. We explored how small groups worked together, without tutorial guidance, on the task of composing a melody with narrative intent, using the notions of similarity and contrast. Our analysis focused on how participants used the DTMI during their session, not only as a tool to make music but also as a platform to discuss their ideas and record their discussion and decisions.

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 that support the manipulation of musical structure. We therefore developed a bespoke DTMI (Franceschini 2021), which we briefly describe in the next section. A full description is provided in Franceschini (2020), along with the full rationale for its development. Further on in this article, we will describe how we configured the application to accommodate the needs of the study we are presenting.

4. A DTMI TO COMPOSE MELODY

We developed a bespoke DTMI application through an iterative evaluation-improvement cycle in a series of studies (Franceschini et al. 2014, 2020). Figure 1b shows a screenshot of the DTMI application, which was designed to be operated from anywhere around the tabletop, as demonstrated in Figure 1a. The design of the application is loosely based on a piano-roll metaphor, which is suitable to graphically represent melodic contour. The interface is composed of multiple short blocks, representing short melodies, that 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 of the blocks 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.
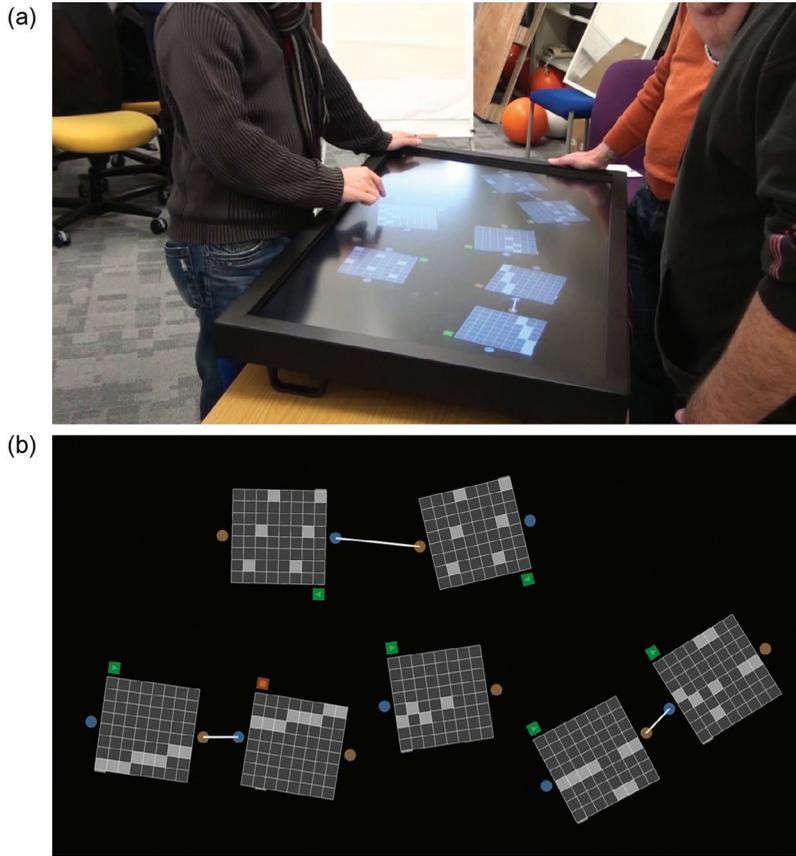
Figure 1: (a) a still frame from one of the sessions with a group of three participants. (b) a screenshot of the DTMI used in Figure 1a.
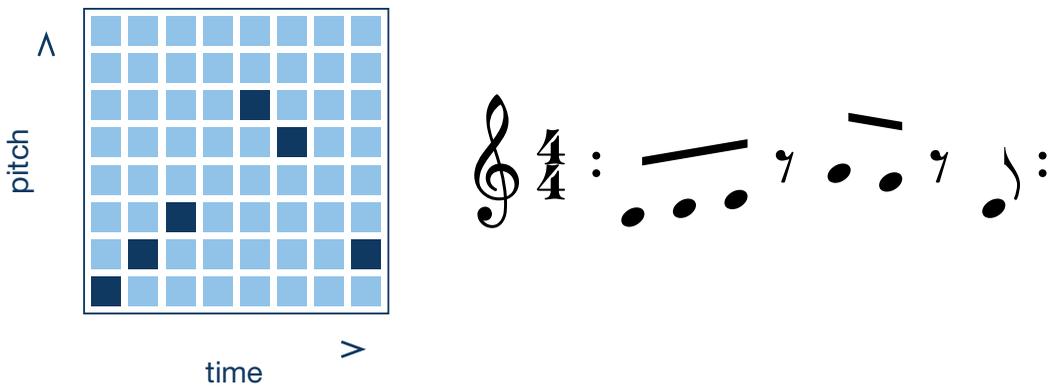

Figure 2: Left: block representation, extracted from the applications' logs, as used in the analysis. Right: staff representation of the block on the left, assuming a C major diatonic scale between C4 and C5.

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. The software is released as open source (Franceschini 2021).

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 available in Franceschini (2021).
- *General discussion:* We asked the participants to discuss among themselves the notions of similarity and contrast in terms of anything they wanted or found useful, and not necessarily in relation to music. The goal was for them to become aware of their mutual views and to agree on a set of principles to judge similarity and contrast to use for the remaining of the session.
- *Musical discussion:* We asked the participants to gather around the DTMI and use it to discuss how the criteria they had just discussed could be mapped onto music. We encouraged them to use the DTMI freely by producing shorter or longer melodies and discussing whether and how they thought they were similar or contrasting.
- *Storytelling:* We asked the participants to invent a short story and compose music to describe the story using the notion they had discussed thus far. When the group decided they had achieved their goal, we asked the participants to briefly summarize the story and describe how the music they composed related to it.
- *Post-session questionnaire and debriefing:* To mark the end of the sessions, we asked each participant to complete an individual feedback questionnaire (Franceschini 2021) and to provide additional comments on how they felt during the session, whether they liked working as a group, whether they felt they contributed to the group work or learned from it and so on.

We required and obtained written consent 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 to the participants that they could request deletion of their data up to the point of anonymization, 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. DATA COLLECTION

We collected data from a variety of sources – including video recordings, questionnaires and application logs – to cross-validate findings in order to assess their credibility and address the issue of validity. 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.

- *Video recordings* provided an exact record of what people did and said during the experimental sessions. We used a single camera mounted on a tripod placed in close proximity to the activity area, so that both the tabletop surface and relevant features of the participants could be recorded – such as hands, stance, spatial location and so on. These videos recorded the verbal discussions between participants 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 the participants (Xambó et al. 2013).
- *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 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 context for analysing the 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 participants to mitigate acquiescence. Furthermore, we encouraged per-statement free comments to complement the categorical answers.
- *Application logs* were recorded by the tabletop applications and included information such as interaction events and the music that the participants composed. These logs were machine-processed in order 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.

7. DATA ANALYSIS

We investigated whether and how people made sense of, and used, the DTMI 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 task so that there were no right or wrong answers: instead, the task was 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.

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.

7.1. Analysis of the DTMI as a collaborative exploration tool

We analysed the video recordings of the sessions to understand how the DTMI could support the group discussion of musical concepts (SQ3). In doing so, we used the following themes, inspired by the frameworks proposed by Hornecker and Buur (2006) and Bryan-Kinns and Hamilton (2012).

- *Mutual Awareness (MA):* to analyse the participants' awareness of each other's contributions and how they used newly contributed information.
- *Mutual Modifiability (MM):* to understand whether all the participants were able to modify each other's contributions and whether they did so in an egalitarian or hierarchical way.
- *Externalization (Ex):* to see if the participants were able to use the shared objects to focus and base their discussion on and to investigate the capacity of such objects to represent the abstract concepts being discussed.

7.2. Analysis of the use of similarity and contrast

We decided to use two additional themes to analyse the discussions and melodies produced, in the same way we did in our previous article (Franceschini et al. 2020). 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. Two sub-themes emerged from our previous work, and we found them useful to reuse them this time: the notion that *similarity is not identity*, but a nuanced property that depends on many different aspects, and the need for *comparability and relatedness* to produce meaningful comparisons.
- *Use of criteria for similarity and contrast in suggesting narrative*, to see whether and how participants worked with melody to express a narrative using the criteria they had previously developed. In our previous analysis (Franceschini et al. 2020), four criteria emerged from the data; thus, we reused these as themes to organize the present analysis. The themes 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.

7.3. Analysis of the storytelling exercise

We analysed the melodies based on the participants' explanations of how they related stories and melodies. Since the melodies are composed of a series of blocks, similarly to Figure 1, we computed three metrics block by block, which we explain below. The DTMI was configured to use blocks with eight temporal divisions, presenting a full octave, from C3 to C4 of the MIDI range, in a major diatonic scale. The blocks were therefore considered as lists of length up to eight along the time axis – containing values between 0 and 7, corresponding to the active squares in each block (Figure 2). For simplicity, pauses – missing notes – were not considered in any of the following metrics.

- *Mean:* This was computed as the average of the values in the list, considered as points in a continuum. The mean was considered to provide a sense of 'big picture' contour, a contour for the whole piece.
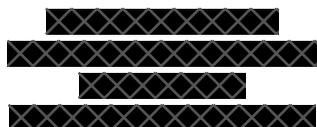
- *Shannon entropy:* Each block B_i was treated as a discrete random variable to compute Shannon entropy. In the example shown in Figure 2, the variable has values (outcomes) 1, 2, 3, 6, 5, 2 based on the notes present in the block. Pauses/rests are not included. Entropy is then calculated as

$$H_i\,(B_i) = -\sum_{j=1}^{n} \mathrm{P}\,(b_{i,j})\,\ln \mathrm{P}(b_{i,j})$$

where P is the probability with which note $b_{i,j}$ occurs in block B_i. In the example above, notes 1, 3, 5 and 6 have $P = \frac{1}{6}$, while note 2 has $P = \frac{1}{3}$. We considered Shannon entropy as an approximation of how melodically 'lively' or 'idle' a block feels. Entropy was computed using the package R's 'entropy' (Hausser and Strimmer 2014).

- *Cross-entropy:* Using cross-entropy as a measure of melodic contrast was proposed by Laney et al. (2015) based on the work of Pearce (2005). We adapted this idea to compute the cross-entropy between pairs of blocks that form a single storytelling melody. Each block is used as a model against which every other block in the melody is tested. The cross-entropy of block B_i against a model constructed using block B_m represents how likely it is that block B_i could be generated using the model as the basis of a zeroth-order Markov chain. This process generated a cross-entropy matrix per melody, in which the value $H_{m,i}$ of cell (m,i) is the cross-entropy of block B_i computed against the model produced using block B_m. We computed cross-entropy as follows:

Let $B_i = (b1, \ldots, bn)$ be a block as shown in Figure 2. Let q_m be the probability density function of block B_m. Since q_m could be 0 for some notes, p_m is defined as

$$p_m\,(j) = \begin{cases} q_m\,(j) & if \;\; q_m\,(j) > 0 \\ \varepsilon & if \;\; q_m\,(j) = 0 \end{cases}$$

(with $\varepsilon = 0.01$) and then used in computing the cross-entropy $H_{m.i}$ of block B_i using B_m as a model:

$$H_{m,i} = -\frac{1}{n}\sum_{k=1}^{n} \log_2 p_m\,(B_i\,(k))$$

To find points of contrast, the most relevant cells are those of coordinates $(m,m+1)$, representing adjacent blocks that are moving forward in the melody. Other cells can provide insights regarding the overall structure of the melody. It is worthwhile noting that the models considered in the present analysis are merely probability distributions, and so they only represent the probability of each note to appear in a block. Conversely, Laney et al. (2015) used Markov chains of order higher than 0, meaning sequences of notes.

7.4. Analysis of the feedback questionnaire

We designed the feedback questionnaire to capture nuances in the participants' experiences that would normally not surface in a quick feedback questionnaire. We expanded the short questionnaire that we used in our previous study (Franceschini et al. 2020) to introduce more items with the aim of capturing a more nuanced picture. Each item also invited free
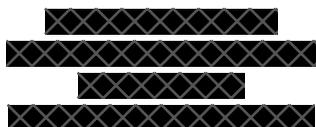
Table 1: Summary of the relationships between collected data, analysis (TA: thematic analysis) and expected outcomes in relation to the aims and questions stated in Section 2.

	Data collection	Data analysis	Yield
SQ1	Video recordings, music	TA of group discussions and storytelling exercise	Criteria for similarity and contrast
SQ2	Video recordings, music	TA of group discussions and storytelling exercise	Composition strategies, participants' understanding of similarity and contrast in suggesting narrative
SQ3	Video recordings, music, questionnaires	TA of group interaction, non-verbal communication	Role of DTMI as a collaboration tool
SQ4	Video recordings, questionnaires	TA of group interaction, non-verbal communication, analysis of closed questions, TA of questionnaire comments	User experience

comments. We designed the items in the new questionnaire to fit within the following themes:

- *Discussion (Di):* to investigate the participants' feelings of satisfaction and involvement with the discussion.
- *Outcome (Ou):* to investigate the participants' satisfaction with the musical material produced (musical outcome) and their confidence and ability to discuss and make music (personal outcome).
- *Interface (In):* to investigate the participants' feelings and attitude towards the DTMI in terms of usability and its role as a discussion mediator.
- *Engagement (En):* to investigate the participants' sense of involvement in the collaborative music-making process. The items under this theme were partly inspired by the discussion of the flow questionnaire and the experience sampling method of Moneta (2012).

Table 1 summarizes the relationship between research questions, data sources and analysis results.

8. RESULTS

Twenty-four participants volunteered for this study and were divided into eight groups of three participants each. Participants were recruited among personnel based on the university campus by posting flyers, circulating e-mails and by word of mouth. Some of the participants were returning from our previous study (Franceschini et al. 2020); therefore, we took care of placing at least one or two new participants in each group, although this was not possible in one case. The sessions lasted between 36 and 61 minutes.

8.1. Demographics questionnaire

Table 2 summarizes the demographic data collected with the pre-session questionnaire. We found that fourteen participants declared having had some exposure to music education for up to two years (mean = 0.79, SD = 0.89), often in school, and thus we considered them beginners. We also considered as beginners those who were not currently playing a musical instrument
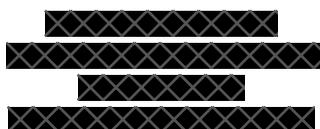
Table 2: Summary of the answers to the demographics questionnaire administered at the beginning of the sessions. The numeric column labels refer to five-point Likert scales from 1 (lowest) to 5 (highest).

(a) A1: Have you studied music?

	No	Informally	Formally
Beginners	7	5	2
Non-beginners	0	1	**9**
Total	7	6	**11**

(b) A2: Do you play a musical instrument?

	No	One	More
10	3	1
0	2	**8**
10	5	9

(c) A3: Have you ever composed original music?

	Never	Occasionally	Often
Beginners	11	3	0
Non-beginners	4	2	4
Total	15	5	4

(d) A2.1: How would you rate your skills on your best instrument?

	1	2	3	4	5
4	1	1	0	0
1	2	**6**	0	1
5	3	**7**	0	1

(e) A3.1: How confident are you in your ability to compose original music?

	1	2	3	4	5
Beginners	8	5	1	0	0
Non-beginners	3	2	2	2	1
Total	**11**	7	3	2	1

(f) A3.1: New/returning status

	1	2	3	4	5
New	5	3	1	2	1
Returning	6	4	2	0	0
Total	**11**	7	3	2	1

even though they had some music education in the past. The remaining ten had studied music more or less formally for at least three and up to twelve years (mean = 7.2, SD = 2.78); therefore, we considered them 'non-beginners'. Across all the participants, they rated their self-confidence in their ability to make original music generally low, with 1 out of 5 being the most frequent answer. This may sound counterintuitive, given the number of returning participants and given the general increase in self-confidence reported in the previous study (Franceschini et al. 2020). However, in practice these two studies were separated by several months during which the participants had very few occasions of making music, as many of them confirmed in the post-session debriefing.

8.2. Feedback questionnaire

Table 3 summarizes the feedback data collected with the post-session questionnaire. The full questionnaire is available in Franceschini (2021), and this section frequently refers to its items directly.

- *Engagement:* Items B9 to B18 cover feelings of being engaged, in control and contributing during the various activities. Participants reported feeling a little more in control during the composition task (B10) than during the initial discussion (B9). Participants tended to contribute equally to the initial discussions, although at times one participant acted as a moderator. Participants also tended to avoid preventing the others
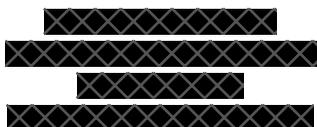
Table 3: Summary of the answers to the feedback questionnaire administered at the end of the sessions. The column labels refer to the feedback questionnaire in Franceschini (2021), and the row labels are SD: strongly disagree, D: disagree, N: neither agree nor disagree, A: agree, SA: strongly agree.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26
SD	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	9	0	0	0	0	2	4
D	0	1	1	3	0	3	1	2	4	2	0	1	1	5	0	1	2	4	9	14	0	1	1	1	10	3
N	3	6	8	9	3	7	2	2	7	6	5	5	3	8	6	4	6	3	5	1	3	6	8	5	2	8
A	14	14	14	9	17	9	12	11	12	14	14	14	13	10	13	15	15	13	2	0	17	11	12	15	9	7
SA	7	2	0	3	4	5	9	9	1	2	5	4	7	1	5	4	1	4	1	0	4	6	3	3	1	2

from approaching and using the DTMI during the composition task, thus encouraging everybody to play their part. Feeling the possibility of taking control and having the ability to give control up in favour of other participants may explain why participants generally felt more in control during the composition task – 'sometimes a little too much' – than during the discussion.

- *Perceived quality of the collaboration (discussion):* Items B12 to B14 cover the individual contributions to the collaboration. Generally participants felt that the sessions were 'very relaxed' and did not feel under pressure from the other participants. Many participants were satisfied (B1) with how their 'discussion progressed, and new ideas emerged', as 'it was interesting comparing notes with other people'. One participant thought that the discussion was 'definitely too brief for that complex concept', and one group acknowledged having 'lost focus a couple of times'. To various extents, participants considered the discussions useful in 'being more aware of [similarity and contrast]' (B2), although often comments were made regarding the 'need [for] further discussion'. Items B16 to B18 covered the participants' opinion of the quality and ease of group work. Nineteen participants thought that the final piece of music reflected the way in which the group worked (B16), and that communicating and discussing their ideas and intentions was reasonably easy (B17).

- *Perceived quality of the musical outcome:* Items B4 to B6 concerned the participants' opinion on the final exercise. Answers to item B4 ('The final result is a nice piece of music') were highly polarized between disagreeing and strongly agreeing. We used the vague term 'nice' on purpose to elicit strong answers and comments. Instead of 'nice', the melody was regarded 'more of an example', with 'much work still needed'. Many participants commented along the lines of 'the idea was nice, not sure the end result was', and 'I like it, but I'm not sure it's nice'. Fourteen participants agreed that the piece of music was 'original' (B6), but comments suggest that the stories they invented were not very much.

- *Personal outcome:* Comparing items A3 and B26, regarding whether participants have composed original music in the past and will do so in the future, reveals that participants would like to attempt making more original music in the future, but only if and when they feel confident enough. Generally, comments agree that 'I may try, but it will take some radical improvement of my composing skills to do', and that 'this study would motivate me to study how to compose original music'. Reasons for
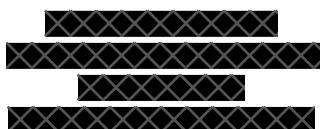
attempting music-making again in the future are also seen as important, and these can range from 'lullabies for grandchildren' to work as 'part of my [introduction to music] course'.

- *Interface:* Items B8 and B19 to B24 covered the participants' experience with the DTMI. This was considered a good medium for discussion (B8), 'especially during the first step'. Some participants felt it was too musically constrained and missing some desirable functions, such as duplicating blocks to facilitate incremental edits and comparisons. Overall, sixteen participants considered the DTMI 'not frustrating' (B19), and 23 considered it 'not confusing' (B20). This was not without caveats: for example, some participants found it difficult to point their fingers at exact locations on the screen. This could be a consequence of the fact that the touch-sensitive glass panel was separated from the LCD panel by a few millimetres, creating a slight parallax misalignment between the point that the finger touched and the point where feedback was drawn. This in turn made hitting the play/stop button particularly frustrating – 'just to stop playing' – and one participant remarked that this was limited to 'the technical parts that are out of your control: the quality of the touch screen did not seem great'. This suggests that larger controls might be necessary with touch-screens of these dimensions, as we had already experienced in previous iterations (Franceschini et al. 2014, 2020). The feedback that the DTMI provided was rated adequately clear (B22), and the interface made it relatively easy to communicate and discuss ideas with the group. However, some participants felt that using the interface to communicate was too slow to do so effectively, while others remarked that a musician might need additional functionality to communicate musical ideas. Overall, this suggests that the DTMI was adequate, though improvable, to support the discussion of a group of people of mixed musical experience, as the experts can easily slow down to meet the pace of the novices, and the novices found enough functionality for what they needed to communicate.
- *Preference of group work vs individual tutoring:* Ten of the twelve participants who also participated in our previous learner–tutor study (Franceschini et al. 2020) stated that they preferred working as a group compared to working individually with a tutor, mainly because they felt they could communicate more, and more freely, as a group of peers, as opposed to feeling constrained in a structure that they perceived as too regulated and 'one-way'. One often-quoted reason was in fact that, this time, it was 'easier to make decisions' as a group, since 'you can share and mix your ideas with the group and […] if you have a doubt, you can share it with the group and go ahead easily'. Two returning participants in a group agreed that the group session

> was much more challenging, which was a great thing as we had to exchange our ideas of similarity and contrast, and most of the time this was happening outside the context of music as none of us, as far as I understood, was a musician.

Arguably, the structure provided by our previous study (Franceschini et al. 2020) helped participants to progressively become familiar with the notions of similarity and contrast in melody and how to use them to produce a sense of narrative. However, the widespread appreciation of the group discussion and

the ability to exchange ideas and to learn from different points of view confirm that tabletop interfaces are particularly well suited for group work, and that they facilitate sharing and discussing information.

In summary, the participants had a generally pleasant experience; they felt comfortable in discussing the topics and being able to undertake the storytelling composition challenge. In the end, more than 60 per cent of the participants agreed that the discussion and group work helped them understand the role of similarity and contrast in music (B2 and B3), and more than 90 per cent felt at least neutral towards the two statements. Based on the assessment provided by the participants in the post-session questionnaire, the DTMI was confirmed to be adequate as a mediator for discussing quite complex musical concepts.

8.3. Thematic analysis of the sessions

The following is the analysis of the sessions based on the video recordings and corresponding transcripts.

8.3.1. Criteria for similarity and contrast

With half of the participants returning from the previous study on the same topic, and with half of the groups referencing what was discussed in their previous individual sessions, it was not very surprising that no new criteria for similarity and contrast emerged in this study. This could be explained in two ways: first, criteria from the first study were common everyday criteria, so it was likely that they would come out again; second, having at least one returning participant in each group mentioning their previous session might have primed the group and possibly limited the breadth of the discussion.

8.3.2. Types of discussion leaders

We call a member who leads the group discussion at any given time during the session a 'discussion leader'. Discussion leaders could be identified in all the groups, although it was not always the same person who led both the general and the musical discussions. In some cases, leaders were clearly identifiable at the beginning of each discussion activity, as they were those posing questions and summarizing focus points. One such example is as follows:

1: Ok. Dissimilar things can be things that can feel different.
3: So the obvious criteria would be shape, size, colour …
1: So, like appearance, would we be able to consolidate those three into appearance?
2: I like appearance.
1: If we discuss how those map onto [music] like size as length, breadth as scale … [pause] Function maybe a little? Like, is that a musical … music for enjoyment or a fire alarm? They are sounds for different purposes
3: Yeah.
2: Totally.
1: And the combination of instruments making a sound, versus a computer making a sound.
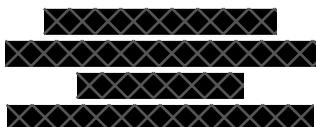
In other cases, instead, the group 'elected' their leader based on how knowl-edgeable they were perceived to be. This was not explicit, but rather shown by participants progressively and increasingly agreeing with the emerging leader. Furthermore, this model was rather fluid, as different leaders could emerge during the same discussion phase, depending on the points being discussed. In the following excerpt, participant 2 does not take the role explicitly, but becomes apparent when examining the body language of others who are gradually more likely to turn to participant 2 rather than to each other, as if they were prompting a response from participant 2.

> 2: I'd say all boomerangs are similar, because they come back, and you can use them to hunt.
> 1: Well, not all of them surely are for hunting … like the star ones, I don't think they were used for.
> 2: Yeah, probably.
> 3: So, what do we say? Some boomerangs are more similar than others?
> 1: I guess …
> 2: You can say that not all of them are used for the same purpose, but they still come back if they don't hit anything, so that makes them all boomerangs.
> 1: Yeah.
> 3: Yeah … I suppose …

8.3.3. Styles of discussion around the DTMI

The second part of the discussion revolving around music was focused on identifying similarity and contrast in melody. As in the general discussion, no essentially new criteria emerged compared to those found in study 1.

Videos show that, in all cases, participants spent at least a few seconds playing around with the DTMI, trying to understand how it worked. In all but one case, returning participants explained to new participants how to use the interface, except for the group formed entirely of returning participants. After at most one minute of exploring the interface, the groups refocused on discussing the topic. Sometimes, one participant would explicitly prompt the group to start working – 'shall we focus on similarities and contrast?' – while in other cases the participants produced some short melodies inde-pendently and then started discussing them with the others. This can be considered evidence of Mutual Awareness (MA), since in both cases there was a moment in which the participants acknowledged explicitly each other's work and began discussing it. The fact that the users could effortlessly create and discuss short melodies on the DTMI can also be considered evidence of Externalization (Ex), highlighting the role of the DTMI as a support medium and a mediator for discussion. Furthermore, nearly all the melodies discussed were subject to some non-conflictual modification by participants other than their original creator, and this is evidence that the DTMI enables Mutual Modifiability (MM).

Two distinct styles of interaction and discussion were observed: *turn-taking* and *continuous interaction*. In turn-taking (Figure 3), one participant at a time stepped closer to the table for the shortest amount of time necessary to create a new example, or to make changes to an existing one (MM), and then stepped back to discuss the objects on the table (Ex). The sequence shown in Figure 3 shows a participant approaching and leaving the tabletop, while the other two stand back and wait, and lasts for about 30 seconds. In this way, partici-pants ensured that they all could have a clear view of the DTMI's surface and
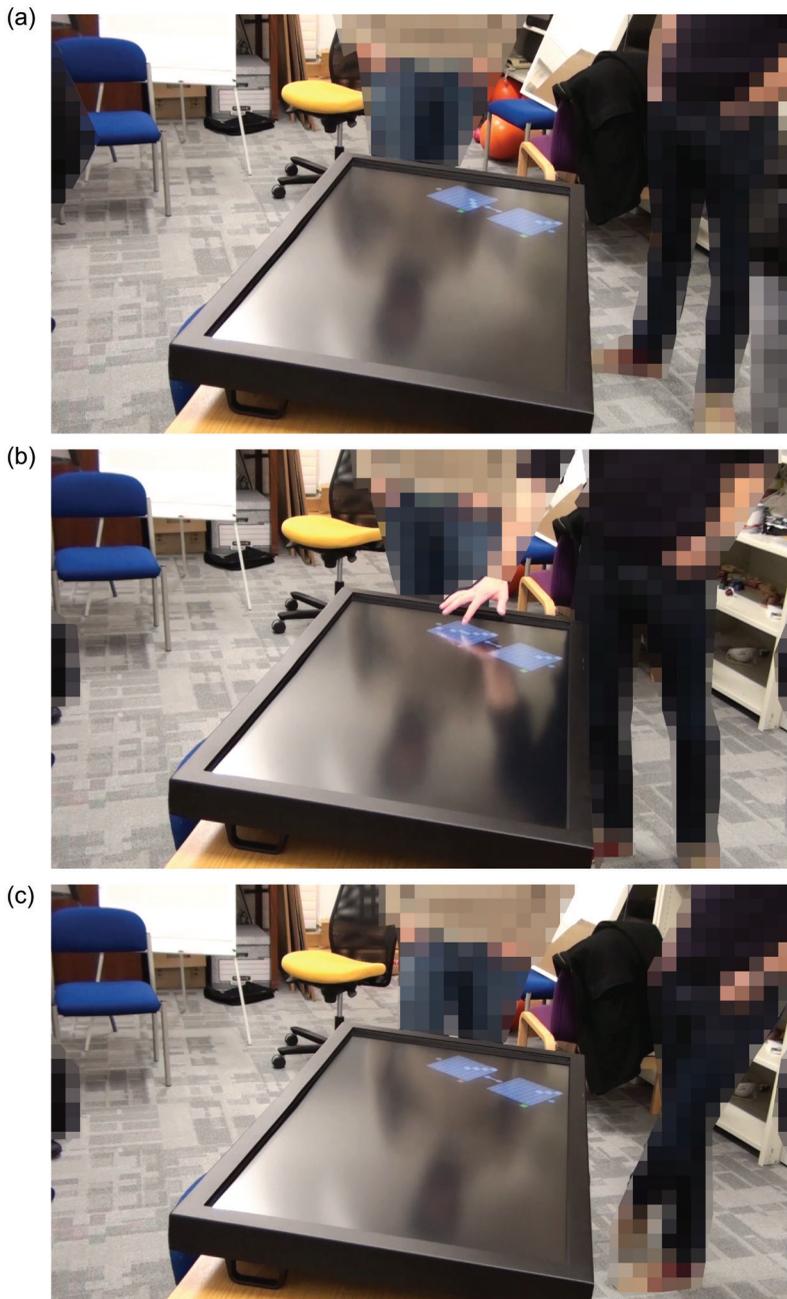
Figure 3: Sequence of vignettes illustrating the turn-taking interaction style.

also provided the others with opportunities to step in and make changes or propose new examples. Turn-taking was found to coincide with slow-paced discussions, in which participants preferred examining a few options in depth instead of producing many different alternatives (Ex).

In continuous interaction (Figure 4), either two or all three participants stood close to the table for longer periods of time and worked together making

Figure 4: All the participants engaged in continuous interaction.

frequent changes at a fast pace (MA, MM). In this way, pairs of participants typically focused on discussing details and variants of the block on screen, temporarily excluding the other participants from the discussion – although three-way discussions occasionally happened (Ex).

All the groups used turn-taking in the musical discussion phase, although two groups occasionally switched for brief moments of continuous interaction with two participants working concurrently. Although the continuous interaction style was primarily used in the composition task, two groups adopted it during the discussion, at a slower pace to make time for discussing and planning before acting. One group had one participant primarily working on the DTMI, while the other two contributed mostly with discussion and less by interacting directly with the DTMI.

Participants in all the groups contributed to the discussion to different extents. While working in turns, there were more opportunities for everyone to take control of the DTMI than in continuous interaction. This was because the participants explicitly took and relinquished control, often a clear enough signal that others were, or were not, allowed to step in (MA). On the other hand, in continuous interaction, participants who initially tended to contribute less to the discussion engaged more frequently with the group and the DTMI. Video recordings show these participants standing closer to the table, paying close attention to the others' actions and contributing themselves.

8.4. Analysis of the storytelling exercise

We briefly discuss here the outcomes of the storytelling exercises from three groups. We identified the following three strategies that the participants used when performing this exercise; therefore, we chose three exercises that were particularly representative of each.
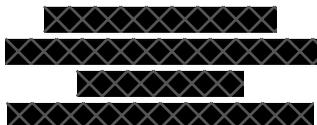
1. The use of similarity to mark related situations was used to create a sense of structural coherence across different parts of the melody that were meant to be related.
2. The use of different musical themes to mark different situations was also used to create a sense of structure by combining distinct sub-clauses in the stories with dissimilar sections in the melodies.
3. The use of tension resolution to convey a sense of evolving narrative involved the use of contrast between melodic phrases to match the unfolding of the narratives.

As can be expected, most groups used more than one of these strategies. Throughout the following analysis, we refer to the diagrams in Figures 5, 6 and 7. Our interpretations of entropy and cross-entropy are tentative and based on a previous paper showing cross-entropy as a useful metric for analysing melodic sections by similarity and contrast (Laney et al. 2015).

Example 1 (see Appendix 1): *A pirate tries to sell some loot, the deal goes wrong, he escapes, and goes back to plundering.* The story begins with the pirate 'happily going up and down between potential buyers' in blocks 1 to 4. In block 5, a sudden change of pace – signalled by a drop in entropy, from 2.2 to 0.9 bits – marks a change of scene, where the pirate is finally making a deal. However, in block 6, a similar yet faster-paced sequence of three notes marks a change in the mood of the scene, introducing the subsequent four blocks (7–10) in which the pirate rushes away, being chased, eventually making it back to his ship and setting sail for new adventures (block 11).

The change of pace between block 4 and block 5, represented by an entropy drop, marks a moment of tension in the story, according to the participants, when the mood changes because of the trouble arising for the pirate making the deal. Block 6 represents a step towards the next change of pace in which the pirate is being chased down – this is signalled by the average pitch, or 'big picture contour', decreasing in blocks 5–7. The rhythmic figure in blocks 7 and 8 is very similar to the one used in blocks 1–4, suggesting similarly lively action, also suggested by closer values of entropy to those of blocks 1–4 than to those of blocks 5 and 6. However, the difference between the highest and the lowest squares in the blocks is considerably smaller, and the notes are mostly in the lower end of the octave – following the previous change in the average pitch – suggesting that the pirate may be moving cautiously, hiding whenever he can. Blocks 9–10 represent a happy resolution of the troublesome part of the story, with contour rising in subsequent ramps, leading to a calmer, more positive looking situation in block 11.

Example 2 (see Appendix 2): *Birth and life and death of a person.* Group 2 mapped the story onto the melody by describing different 'ages' in single blocks: block 1 represented the moment of birth and infancy, characterized by 'high, happy notes, quite chaotic', and overall quite lively (H_1 = 2.2), followed by a block representing youth – 'not so much going on', where the contrast between blocks 1 and 2 can be seen by their rather high cross-entropy $H_{1,2}$ = 6.4 – and then by a block representing adulthood – 'get a job, live life, but progressing to old age', $H_{2,3}$ = 5.8. Old age and death come in blocks 4–6, where block 4 represents 'health degrading', block 5 is 'a flat line … and then nothing' in block 6. The group expressed their intention of telling a story using different phrases that suggest different moods: blocks 1 and 3 are characterized
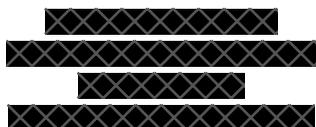
by lively up-and-down motions and wide intervals to suggest a state of chaos and busyness, and block 4 takes that business to a calmer point; blocks 2 and 5 represent the idea of very little going on – block 5, in fact, partially represents death, appropriately having $H = 0$. However, participants made no effort to highlight specific details in this person's life, but rather focused on describing the big picture.

Example 3 (see Appendix 3): *Dr Jekyll and Mr Hyde transforming into each other.* The structure chosen by group 5 has three parts: a theme for Jekyll on the first two blocks, a theme for Hyde on the last two blocks, and the group explained that 'the music changes slowly to represent the transition between the two states' in the four middle blocks. A closer look at each block's entropy reveals that the four 'theme' blocks have distinct entropy values – Dr Jekyll has $H_1 = 2.0$, $H_2 = 1.9$; Mr Hyde has $H_6 = H_7 = 1.5$. Interestingly, the cross-entropies of blocks 1–2 and 7–8 (namely $H_{1,7}$, $H_{1,8}$, $H_{2,7}$, $H_{2,8}$) and their symmetrical entries in the matrix are among the highest, confirming the group's intention of using these to represent the two 'contrasting' characters. Curiously, Dr Jekyll would seem to almost reappear in block 4, as marked by the high cross-entropy with blocks 7–8 and the low cross-entropy with blocks 1–2.

On the other hand, the entropy of the 'transition' blocks 3–6 rises throughout blocks 3–5, starting from a level comparable to those of blocks 1 and 2 – $H_3 = 2.0$, $H_4 = 2.3$, $H_5 = 2.5$ – and then falls – $H_6 = 1.8$ – towards the lower levels that are associated with blocks 7 and 8. This suggests that the transition from the friendly and sociable Dr Jekyll to the evil Mr Hyde is, in fact, a tense moment in itself. The high entropy of these blocks is an effect of the wide pitch intervals used to suggest a state of 'chaotic transition', as explained by the participants. However, when the group explained their reasoning, they made no reference to any tense moment in particular, but instead stated that they simply wanted to represent the 'chaotic transition' between the two states of the character. This suggests that the intention of the participants and the objective features, when taken in isolation, may not be able to reflect sufficient nuances in the roles of similarity and contrast in melody in relation to narrative, but have instead to be considered collectively.

8.5. Summary

We confirmed some of the findings from our previous study (Franceschini et al. 2020) in the sense that the DTMI could provide adequate support and scaffolding for the participants to explore music in a friendly, hands-on way.

We observed various interaction patterns during the different parts of each session. Most notably, we observed two distinct ways of working around the DTMI to discuss and produce music: turn-taking and continuous interaction (SQ3, Section 8.3.3): in turn-taking, individuals take turns to work individually on the DTMI and discuss their work with the other group members; in continuous interaction, all the participants work concurrently on the DTMI while seamlessly discussing their work with each other at the same time. We consider the emergence of these two styles as evidence that the DTMI was conducive to the group music composition activity that we proposed.

As a result of the collaborations, different strategies for composing music with intent emerged (SQ1 and 2, Sections 8.3.2 and 8.3.3). To different extents, our participants felt that working with a group of people of mixed musical experience helped them explore the role of similarity and contrast in conveying

narrative through music, in particular through comparing their experience and ideas about the concepts with those of their groupmates. In this respect, we think that this study was successful in the sense that our participants were able to discuss, understand and use the music concepts that we proposed, and they regarded the DTMI as a very useful tool to mediate and record their collaborative work. This was particularly felt by less experienced participants in relation to those who were more musically knowledgeable.

Most importantly, the feedback provided by the participants indicated that they felt encouraged by the challenges (SQ4, Section 8.2) to engage in an unfamiliar activity such as music-making. Getting novices to compose music is a hard problem, and doing so in a way that is inviting, enjoyable and informative for less experienced users is particularly hard. This study showed one way in which this problem can be tackled through the use of digital table-top technology and of appropriate software and conceptual tools.

9. LIMITATIONS

We recognize two problematic aspects in our study, the first regarding the number and experience of our participants and the second regarding progress tracking. First of all, 24 participants in eight groups of three constitute a relatively small cohort. This certainly 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. However, having such a small, self-selected cohort risks having obtained a non-representative sample in terms of musical experience and interest in music. We considered this limitation when analysing the demographics data (Section 8.1) 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, due to a lack of some form of aptitude testing or graded assessment, we are grouping together participants of varying musical ability. However, we considered that introducing such an assessment into our sessions would have unnecessarily complicated the sessions without adding significantly useful information. Instead we did use the number of years of musical education and experience as a rough proxy measure. Lastly, twelve out of 25 participants had already participated in a related study we ran prior to this one (Franceschini et al. 2020).

The second problematic aspect of this study is that, while the study allowed us to gain considerable insights into the individuals' understanding of the notions and the groups' composition practices (SQ1–3), we were unable to 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.

10. LESSONS LEARNED

Our participants worked effectively with similarity and contrast to produce original music with a narrative intent. 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. All the participants expressed satisfaction with the way they worked in a group of peers,
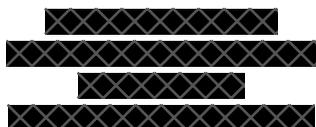
especially how they were able to quickly discuss ideas and progress towards their music composition goals. The less experienced participants particularly enjoyed being able to throw ideas around in a friendly environment and being able to quickly express them using the DTMI and to give musical forms to their ideas and discuss them more effectively than if they did not have access to the tool.

Our choice of using similarity and contrast comes largely from our previous study (Franceschini et al. 2020) in which individual participants explored the concepts with guidance from a tutor through a set of practical musical exercises performed on the DTMI. Therefore, as the present study was designed as a follow-up with a focus on collaborative group work, the choice of musical concepts was natural. We however considered that the structure of the previous study would probably not lend itself to a group setting without feeling a little forced; therefore, we had to rethink the type of activities that could be useful to introduce our participants to the use of similarity and contrast in melody composition. We adopted a hands-on approach that we felt was particularly well suited to the kind of interaction we wanted our participants to engage in: 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.

11. CONCLUSION

Music is complicated, and it is clear that technology alone can only partly help. The DTMI that we developed proved to be adequate in supporting a mixed group of experienced and inexperienced people in exploring aspects of melody and allowed them to explore how music can be composed with reference to extra-musical material such as a narrative. The DTMI provided a simplified representation of melody that transformed music from an arguably complex and intimidating entity into something that could be easily manipulated without requiring extensive specialist knowledge. We have established the transformational capability of the DTMI previously for individuals in a tutorial setting (Franceschini et al. 2014, 2020), so we moved to investigate the technology and activities in an undirected group work scenario. The design of the DTMI, combined with the physical properties of what is essentially a table around which groups of people can gather to work together, showed that the DTMI is an excellent equalizer that facilitates discussion and music composition through its interface and music representations. We asked our participants to compose melody to tell a short story after discussing the concepts of similarity and contrast. As a result, groups composed of people of varying degrees of musical expertise could discuss music at a level that they were all comfortable with – using a language and a set of tools that was understandable and usable by all of them – and compose simple pieces of music with narrative intent using the concepts of melodic similarity and contrast. In fact, in nearly all the cases, the participants came out of the studies knowing that they were capable of creating some music, however crudely, and also enriched with insights into the process of music-making with narrative intent, which can be beneficial to follow and appreciate better a piece of, for example, programme music.

We argue that, with their flexibility, DTIs may be in an ideal position with respect to facilitating access to music for people who want to improve their understanding and appreciation of music but may not be necessarily keen on
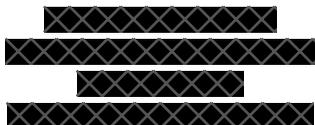
engaging in more demanding music studies – although we recognize that facil-itating the first step is often enough to get enthusiasts engaged. We adopted a similar design approach to the one we used in our previous study (Franceschini et al. 2020) and found it helpful in generating a new user experience in a differ-ent setting – that is, groups vs singles. Our experience in designing this study suggests even more that our design approach can be adapted to areas of knowl-edge that are not necessarily music but resembling its complexity. However, the inclusion of more participants and a looser session design only reinforced the idea that increased complexity can lead to increased fragility as well as cogni-tive overload. This confirms that the involvement of domain experts in design-ing this kind of combinations of technology and activities is crucial to their success, but also makes it clear that a design that descends on the users from above may pose challenges for some users. Further study using participatory design is in order to make sure that the technology and activities reflect both the needs and interests of the end-users – to optimize relevance, usability and enjoyment – and of the domain experts – to ensure the most appropriate activi-ties, techniques and representations are embedded in the product.

11.1. Future research

Although the participants in this study were successful in working through their tasks and showed evidence of having acquired and elaborated knowl-edge of the musical notions proposed, satisfaction with their work and the quality of interaction with their peers varied. This was expected given that the sessions were relatively short and one-off. In a longitudinal study, returning participants would have more opportunities for exploring music-making more deeply as well as the DTMI as an instrument and composition tool.

Involving the participants in an ongoing design process may also result in a more enjoyable, immersive and inclusive experience (Holone and Herstad 2013; Rodà et al. 2021; Wintermans et al. 2017), which would benefit the participants in that they would have a chance to reflect on the musical mate-rial before and after using the DTMI, in addition to while using it.

Collaboration and connectedness across long distances has been a recur-ring theme during the COVID-19 pandemic. Whether this is our new normal or whether a new pandemic will hit us again in a few years, we have lessons to learn and technologies to explore with regard to moving a part of our lives to shared, virtual spaces. Extended reality (XR), a combination of real-and-virtual environments and human–machine interaction technologies, presents a unique opportunity for the development of flexible technologies that can help people connect and interact over distance and engage in activities that we otherwise primarily perform in person, such as working as a group in a shared environment to explore music-making.

APPENDICES

	1	2	3	4	5

	6	7	8	9	10

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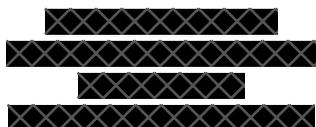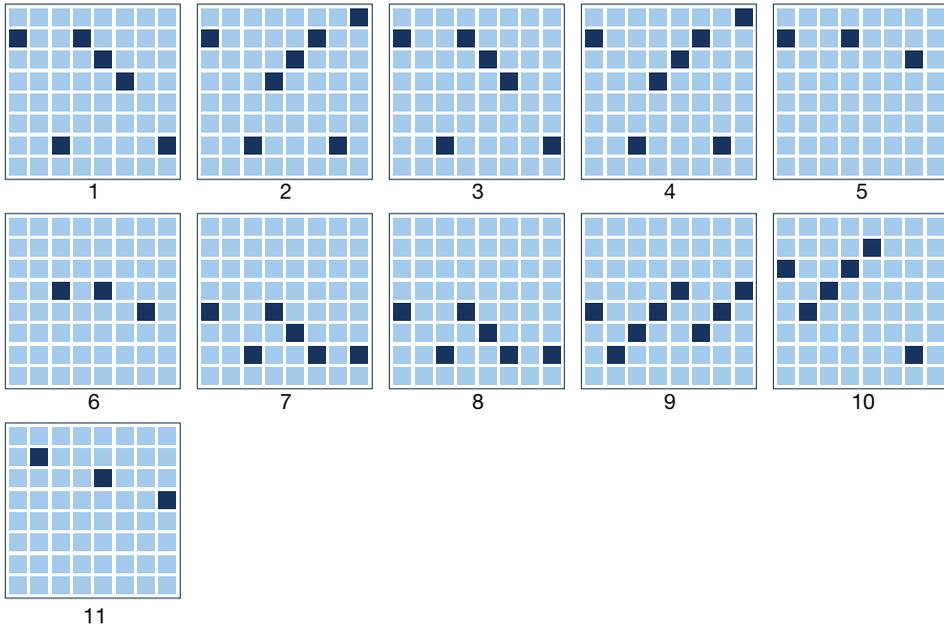
entropy	block	cross-entropy										
		1	2	3	4	5	6	7	8	9	10	11
1.9	1	2.0	2.6	2.0	2.6	2.0	3.8	3.8	3.8	4.6	2.9	2.3
2.2	2	2.2	2.3	2.2	2.3	2.2	4.0	4.0	4.0	4.8	3.1	2.5
1.9	3	2.0	2.6	2.0	2.6	2.0	3.8	3.8	3.8	4.6	2.9	2.3
2.2	4	2.2	2.3	2.2	2.3	2.2	4.0	4.0	4.0	4.8	3.1	2.5
0.9	5	3.2	3.5	3.2	3.5	1.2	5.2	5.2	5.2	5.2	3.3	2.6
0.9	6	4.5	4.6	4.5	4.6	5.2	1.2	4.1	4.1	2.8	3.9	3.7
1.5	7	4.4	4.6	4.4	4.6	6.0	4.6	1.6	1.6	3.0	4.5	6.0
1.5	8	4.4	4.6	4.4	4.6	6.0	4.6	1.6	1.6	3.0	4.5	6.0
1.9	9	4.6	4.8	4.6	4.8	6.4	1.9	2.4	2.4	2.0	4.3	5.0
2.3	10	2.5	3.0	2.5	3.0	2.3	2.7	3.2	3.2	3.5	2.3	2.3
1.6	11	2.9	3.2	2.9	3.2	1.8	2.9	5.1	5.1	4.3	2.9	1.8

Appendix 1: Diagram corresponding to the first example analysed in Section 8.4.
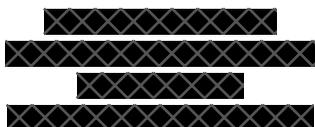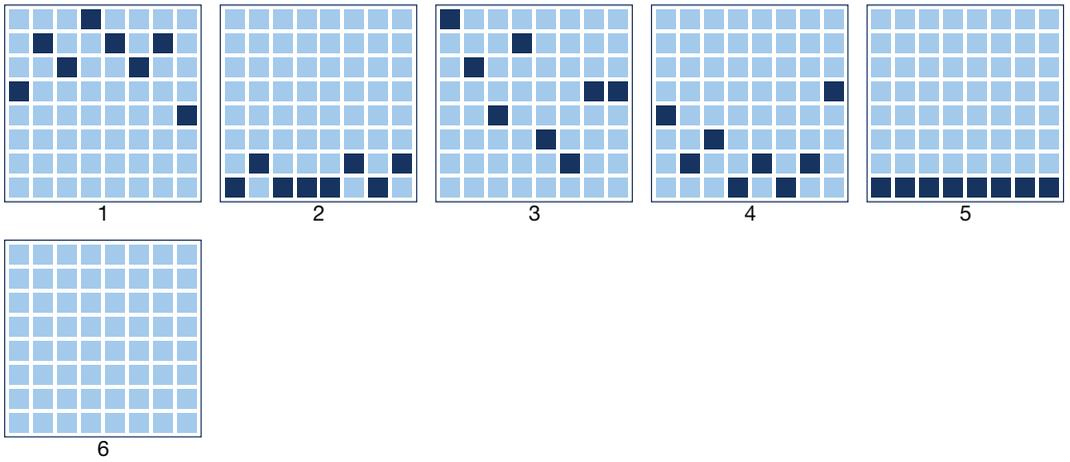
entropy	block	cross-entropy					
		1	2	3	4	5	6
2.2	1	2.2	6.4	3.6	5.5	6.4	∞
1.0	2	6.4	1.1	5.8	3.2	0.8	∞
2.8	3	2.9	5.1	2.8	3.7	6.3	∞
2.2	4	5.5	1.8	4.1	2.2	2.1	∞
0.0	5	6.4	2.5	6.4	4.9	0.1	∞
	6	∞	∞	∞	∞	∞	∞

Appendix 2: Diagram corresponding to the second example analysed in Section 8.4.
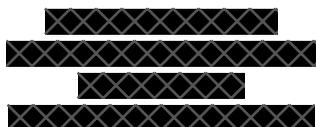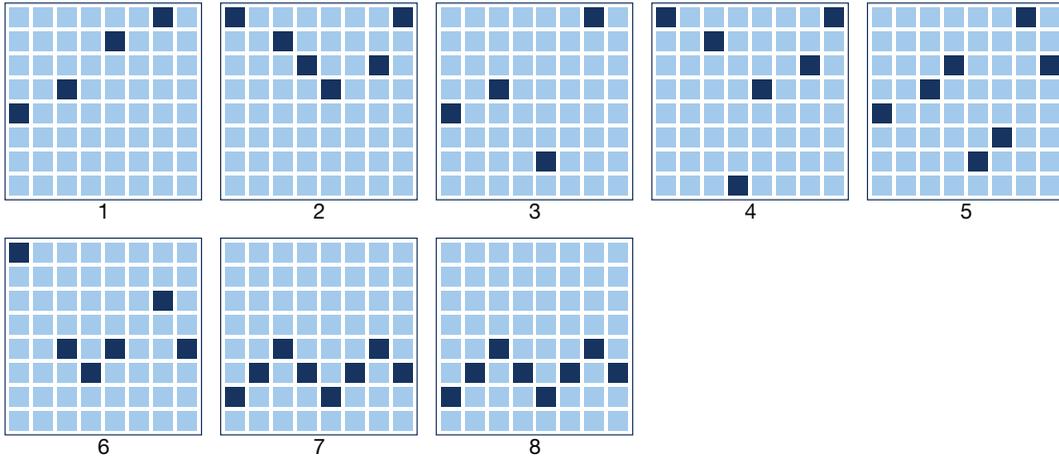
entropy	block	cross-entropy							
		1	2	3	4	5	6	7	8
2.0	1	2.1	3.2	3.0	3.2	4.0	3.2	4.6	4.6
1.9	2	3.3	2.0	4.1	2.7	3.7	4.6	6.0	6.0
2.0	3	3.0	3.8	2.1	3.8	3.6	3.2	3.8	3.8
2.3	4	3.2	2.3	4.1	2.3	3.9	4.7	6.0	6.0
2.5	5	3.7	3.1	2.9	3.8	2.6	2.7	2.9	2.9
1.8	6	3.9	3.8	3.9	4.3	3.4	1.9	3.1	3.1
1.5	7	5.3	6.4	4.3	6.4	4.4	3.4	1.6	1.6
1.5	8	5.3	6.4	4.3	6.4	4.4	3.4	1.6	1.6

*Appendix 3: Diagram corresponding to the third example analysed in Section 8.4.*

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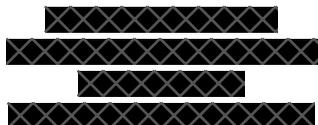
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SUGGESTED CITATION

CONTRIBUTOR DETAILS

Andrea Franceschini is a computer scientist based in the Department of Information Engineering at the University of Padova. In his doctoral studies, he focused on tangible interfaces for engaging music novices into music-making, and has also worked on large-scale online educational projects in STEM disciplines. His research interests include ludic technologies for facilitating access to music, literacy, and critical thinking in non-formal learning contests, and is now a researching non-serious educational video games and interactive media.

Contact: Centro di Sonologia Computazionale, Department of Information Engineering, via Gradenigo 6/A, 35131, Padova, Italy.
E-mail: andrea.franceschini@gmail.com

Robin Laney is deputy director of the Music Computing Lab at the Open University. He is head of the School for Computing and Communications. He is interested in how music works and why it is so significant as a human activity. His team is exploring this through two approaches: first through computational musicology – what can pattern matching and statistical approaches tell us about music? Second, through constructing and investigating human–artificial intelligence collaborative systems that allow mixed-ability groups to make music in a meaningful manner. He is a fellow of the Royal Society of Arts.

Contact: School of Computing and Communications, Jennie Lee Building, Walton Hall, Milton Keynes, MK7 6AA, UK.
E-mail: robin.laney@open.ac.uk

The late Dr Chris Dobbyn was a senior lecturer in computing at the Open University. His research interests included interdisciplinary work in music as well as cognitive science and education.