Psychological benefits of networking technologies in children's experience of ensemble music making

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Abstract

Little is currently known about the possible benefits of using networked technology to enhance ensemble performance. This study explored whether the introduction of specially devised technology – networked tablets using traditional music notation – to a primary school orchestra would enhance the experience of ensemble music. Particular emphasis was placed on how the technology could help children to overcome practical problems associated with ensemble playing for early-stage musicians (e.g., keeping in sync with other players), thereby leading to better engagement with the music and ultimately greater enjoyment. Findings from a thematic analysis of responses from a focus group with eight young orchestra players aged 9–11 years and from an interview with the orchestra conductor, together with indications from the statistical analysis of 28 orchestra participants' questionnaire responses, suggest that the technology did help to

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reduce the practical problems associated with ensemble playing. This appeared to interrupt the downward spiral of frustration and lack of confidence in playing for some young people, and enhanced the likelihood of feelings of enjoyment and belonging.

Keywords

Engagement, ensemble music, motivation, orchestra, psychology, technology

Ensemble music making is a form of collaboration in which the participants actively contribute to a total musical effect larger than individual voices or instruments, through being in musical synchrony. In addition to aesthetic pleasure, the benefits of this activity include "self-confidence; social skills; a sense of belonging" (Hallam, 2010, p. 279). The benefits of ensemble playing are not limited to adult players; we know from existing research that participating in orchestral and ensemble performance of notated music repertoires has been found to confer multiple benefits amongst children and young people. Such benefits include communication skills, a sense of participation in a shared experience that can transcend language and cultural boundaries, critical-listening and self-correcting skills, improved self-confidence, and even empowerment after an experience of isolation (Kokotsaki & Hallam, 2007). Further, these musical and personal skills are transferable to other contexts, are attainable at an early age (Temmerman, 2005) and can influence later vocational outcomes (Abeles, 2004).

However, we also know that such positive experiences of ensemble music making are not universally shared by children and young people because of varying degrees of musical literacy and opportunity in the population. Ensemble music making is a technically challenging abstract activity, one in which "counting is vital in order to keep time, at least to realise which beat is being performed and when to enter or exit" (Goodman, 2002, p. 153). This can be off-putting for beginners who may conclude incorrectly when they experience difficulties that they lack ability or aptitude, likely leading to loss of interest and motivation (Hallam, 1998), and potentially to them dropping out from the ensemble or even from music making altogether. Indeed, in their study exploring the psychological mechanisms underpinning reasons for giving up a musical instrument in children, Evans, McPherson, and Davidson (2013) found not only that a large number of children cease playing their instrument after just a few years of playing, but also that a lack of perceived competence is a key reason for children ceasing to play. Similarly, Hallam (1998) proposed that those who experience failure are more likely to have reduced motivation and to lose interest in their musical instrument.

Research shows that a wide range of factors play a role in children's persistence with playing a musical instrument (e.g., Hartley & Porter, 2009; Hawkinson, 2015; Kinney, 2010), and perceptions of musical ability appear to play a role in orchestral dropout for at least some students (Cook, 2013). Given the high rates of dropout from musical instrument learning, it is not surprising that researchers have called for supportive and flexible teaching environments which facilitate the development of creativity (Hallam, 2010). Further recommendations for mitigating against dropout come from Hallam and colleagues (2016), who have highlighted the need for young learners to acquire "effective strategies" (p. 18) in their practice in order to cope with the increasing demands of a repertoire that necessarily becomes more difficult as a child learns. Moreover, they warn that self-beliefs and enjoyment of performance may be impacted should this hurdle not be overcome, thereby increasing the likelihood of dropout.

Psychological foundations for musical engagement

Longstanding psychological theories of motivation provide established frameworks for understanding the mechanisms underpinning different motivational orientations to musical engagement (for a review, see Hallam, 2002). We know, for example, that self-efficacy – perceived capability – in a given domain predicts greater motivation and persistence in that domain (Bandura, 1977; Schunk, 1995), while within self-determination theory (SDT; Ryan & Deci, 2000) the psychological need of competence – related to the experience of engaging in optimal challenges, feeling confident and effectual in tackling challenges, and receiving encouraging feedback – has also been found to be associated with task persistence and enjoyment across many domains (Grouzet, Vallerand, Thill, & Provencher, 2004; Ryan & Deci, 2000). Recently, Evans (2015) has demonstrated that these relationships hold for motivation to engage with music, and other studies have demonstrated associations between greater musical/instrument self-efficacy and motivation to play, as well as greater enjoyment of playing (Chandler, Chiarella, & Auria, 1987; Hallam et al., 2016; Martin, 2012). Furthermore, retrospective research conducted specifically to examine the fulfilment of the psychological needs of competence, alongside other basic needs for autonomy and relatedness that are outlined in SDT, showed that greater need fulfilment was associated with high engagement in a school music band. In contrast, reduced feelings of need satisfaction were associated with decisions to cease playing an instrument (Evans et al., 2013).

Enjoyment is another well-established factor underpinning motivation, with research showing that enjoying musical activities is a strong predictor of future musical aspirations (Hallam, 2013). This again links to core psychological theories of motivation that help to unpick the importance of enjoyment for continued motivation and engagement. For example, using the SDT framework, the satisfaction of psychological needs within a particular domain has been shown to be associated with intrinsic motivation, which is defined as engaging in activities out of a genuine interest and enjoyment in them, rather than for external rewards (Ryan & Deci, 2000; Sheldon & Filak, 2008). Intrinsic motivation is in turn associated with greater persistence at a task and better performance (Deci & Ryan, 1991), as well as producing greater self-esteem and well-being (Ryan, Deci, & Grolnick, 1995). Kokotsaki and Hallam's (2007) study of music university students' engagement in ensemble music making also highlights the importance of enjoyment. Furthermore, other research has indicated that children who develop a sense of intrinsic motivation early in the learning of their instrument achieve more highly on performance measures (Davidson & Burland, 2006; McPherson, 2008). Elsewhere, Hallam has emphasised the crucial role of enjoyment of musical pursuits if positive personal and social outcomes are to ensue: "the positive effects of engagement with music on personal and social development only occur if it is an enjoyable and rewarding experience" (Hallam, 2010, p. 269).

Finally, the importance of feelings of belonging, which has been defined as the subjective sense of being accepted, valued, included and being an important part of a group (Goodenow, 1993), is related to a further basic psychological need identified by SDT, namely relatedness. The extent to which children's need for relatedness is satisfied in the classroom is a key predictor of academic motivation and performance (Furrer & Skinner, 2003; Goodenow, 1993), and there are also preliminary indications that a sense of belonging or relatedness may be one factor underpinning motivation for engaging in music ensembles (Hallam, 2010; Kokotsaki & Hallam, 2007).

In summary, research suggests that enjoyment, self-efficacy and belonging are key foundations for musical engagement. In turn, evidence on the benefits that accrue from participation in music making (Kokotsaki & Hallam, 2007) suggests that this engagement further enhances these psychological characteristics, thereby creating a positive feedback loop.

Technologies for enhancing ensemble music motivation

Many resources exist to encourage interest in ensemble music making. Figure Notes (n.d.) provides a paper and label-based system for developing notation skills through a progressive approach from graphic notation to full musical notation. Charanga (n.d.) provides an extensive music teaching resource including a combination of digital support and materials to cultivate musical appreciation and performance in schools and has seen significant take-up. In 2014 the BBC started the Ten Pieces project, which now comprises two films and bespoke resources for schools, with the aim of opening up "the world of classical music to a new generation of children" (BBC, n.d.a) through visually engaging performances of music ranging from Handel to Anna Meredith. The BBC supported this by commissioning lesson plans and arrangements with downloadable parts for mixed-ability performance and making them freely available online (BBC, n.d.b).

Furthermore, use of specially prepared paper parts and scores has been long established with publishers such as Chester Music ("Kaleidoscope Easy Music for Varied Ensembles" series, e.g., Elgar, 1998) and Wedgwood Music (n.d.) serving the school ensemble sector with paper-based arrangements graded by ability level. However, even as a plethora of resources help to promote the value of ensemble/orchestral music making and to demystify some of the obstacles regarding notation, there is a need to address directly the rhythmic and temporal coordination for polyphonic music with which children may struggle.

Frameworks for effective technology interventions to improve music learning experiences in schools have been considered for some years. Researchers have previously argued that in the right conditions digital tools can provide "a supportive environment for collaborative music-making" (Charissi & Rinta, 2014, p. 39). Core to Burnard's critical work on reframing creativity and technology is the point that we should place two questions at the centre of new music technology and education projects: how pupils would like to work musically, and what resources they would like to use (Burnard, 2007, p. 38).

In the context of developing tools to support harmonic function discrimination, Manzo (2014) noted that layers intervene between the student's capability to understand the task and her/his ability to control an instrument. In a similar way, the student reading a musical part and trying to perform it in an ensemble setting can understand the task but, as a beginner, can experience latency in performing it due to the number of factors that have to be assimilated (reading notation, looking and listening for tempo coordination, fingering or keying, bowing or blowing, looking ahead). Manzo argued that "by minimising the number of layers between the student and the task, the musical concept can be isolated to some extent and understood" (Manzo, 2014, p. 25).

Existing software apps already address music notation in two ways: (a) training the user to achieve greater fluency in sight-reading musical notation; (b) using music readers or digital music stands that enable the individual user to follow a digital version of the score during practice and performance. Type (a) includes apps such as Music Tutor (n.d.), designed to improve sight-reading through randomised display of notes on a staff which the user is invited to identify. Type (b) includes apps such as Musicnotes Sheet Music Player (Musicnotes, n.d.), which will "preview, transpose, play and print sheet music and guitar tab", and give access to a score library, from a desktop. Such software can certainly assist preparation for the experience of ensemble music making but it does not form a direct intervention into facilitating the experience of playing music in a group through a computing network. The current project aimed to address and to evaluate such a direct intervention using our technology solution to ensemble music coordination for beginners which involves synchronised part notation display to minimise layers (Manzo, 2014) and manage difficulty in a complex task for an individual in a group.

The present study

Building on core theoretical frameworks for understanding motivation, described above, we investigated the psychological benefits of using networked digital scores through the analysis of responses from primary school children taking part in a voluntary school orchestra club to survey-style questionnaires both before and after the introduction of the Networking Technologies and the Experience of Ensemble Music Making (NETEM) system.[1] A number of more specific strands of enquiry were established. First, while positive responses on key variables relating to experiences of orchestra (e.g., self-efficacy, enjoyment and belonging) were expected due to the self-selecting nature of the group of young orchestral players who made up the participants in this study, we wanted to investigate whether there would be any overall changes from before to after the introduction of the NETEM system. Second, and importantly, we recognised that there would likely be individual differences in children's experiences of musical engagement, and therefore explored their perceptions of the NETEM system in relation to variations in their levels of self-efficacy (perception of playing ability), and their enjoyment of the ensemble rehearsals. Third, given previous work which has highlighted the importance of experiences of group membership for motivation to sustain ensemble music playing (Hallam, 2010; Kokotsaki & Hallam, 2007), we focused on how individual responses to technology related to children's sense of belonging to the orchestra.

As well as using quantitative analysis of ratings given in surveys, we investigated the above issues using qualitative analysis of responses from a focus group with a sub-sample of young orchestral players, as well as an individual interview with the orchestra director. Our analysis involved an exploration of the accounts of the children's and orchestra director's experiences of orchestra, their motivation for attending, what they enjoyed and least enjoyed, and what difference the introduction of the NETEM system had made to their experience of ensemble playing. In addition to gaining rich insights into the psychological issues raised above, we aimed to understand the practical consequences of using the technology as compared to using standard sheet music. Inductive thematic analysis was used to analyse the data in line with Braun and Clarke's guidance (2006).

Overall, the present study – funded by the UK's Arts and Humanities Research Council (AHRC) – sought to address the hitherto unexplored potential of NETEM, a computationally networked tablet-display system to improve confidence in mixed-ability ensemble music making. In particular, we investigated how a group of young musicians and their conductor experience, perceive, and respond to the use of a networked notation and display system. To answer the research questions stated above, the following quantitative and qualitative methodology was employed.

Methodology

This was an innovative interdisciplinary project employing mixed methods. An arts/computing practice-led research approach was taken, in which the team was led by a composer and arranger of music for flexibly scored ensembles. Human–computer interaction experts and programming experts led the development of the networked technology, while developmental psychologists led the evaluation aspect of the work, which is the focus of this article.

Development of technology and repertoire

The aim of our NETEM system was to help support mixed ability groups playing music together through a portable, self-contained and wireless digital technology. Work began on the NETEM project in September 2015. This initial period involved the development of the software itself, a

fundamental part of which was gaining feedback from users wherein test screens of possible formats for the dynamic graphical user interface were shown to users as they were prepared; feedback on interaction and display was continually sought throughout the project.

It should be noted that this fieldwork was part of a broader programme of development and testing of the technology.[2] Starting before the application for AHRC funding and then continuing through the project period, the technology was also developed in consultation with an ensemble of university music students, and an advisory group of academics in cognate areas, and cultural leaders from a range of regional and national organisations interested in ensemble music making and technology. This was designed to ground and shape the development of the technology in the key concerns, perceived needs, and aspirations of stakeholders with relevant expertise and experience.

By December 2015, a prototype wireless server/client system had been created which used tablets loaded with scores and individual parts (Eldridge, Kiefer, & Hughes, 2016). Two apps were written: a "conductor" app is used to select which score is to be played and in turn signal the position in the score to the "player" apps, which display parts on individual screens. Because of the technology used, the single conductor app can wirelessly control multiple player apps. To date, this has been successfully applied to a network of 16 tablets.

By January 2016, a working system was established alongside an initial library of compositions and arrangements. The system is capable of responding to and is triggered by tap tempo (tap out the beats on the screen at the tempo you want for the first bar of music, and then the system starts). In response to user feedback, the team added functions to enable the music director to choose to let the system run by itself; pause and/or adjust the tempo during performance by intervening with a new tap tempo; and conduct "manually" (beat time currently through tapping) throughout the performance.

Design

The study employed a mixed-methods approach in order to capture first-hand the children's and music teacher's experiences of using the NETEM system, and to evaluate the perceived impact on a range of factors understood to be important for ensemble music playing.

For the qualitative part, a focus group with a sub-sample of the young orchestra players was carried out to explore the children's own perceptions, motivations, and experiences of using the NETEM system during orchestra rehearsals. The sub-sample was selected on the basis of: the children's own enthusiasm for contributing their views; the conductor's guidance to ensure that the group included a mix of children in terms of age, gender, ability, and time with the orchestra; and practical considerations regarding availability at school at the scheduled time of the interview. An in-depth interview with the music teacher, who also conducted the orchestra, was carried out to gain their perspective on pupils' experiences of ensemble music playing and on the perceived impact of the NETEM system to support engagement in ensemble playing.

A repeated-measures quasi-experimental design was employed for the quantitative aspect of this research using quantitative measures at pre and post time points to capture change and to measure the potential impact of the NETEM system. The questionnaire measures were completed during two separate phases, each of six weeks' duration (see Figure 1). Phase 1 (P1) took place before the technology had been introduced and was intended to operate as a comparison to Phase 2 (P2). The same questionnaire items were used during each phase, with only minor adaptations in P2 to allow for additional questions relating directly to the introduced technology. Attempts were made to match the two phases in terms of the genre and ability level of the pieces played, with a new piece introduced at each phase.
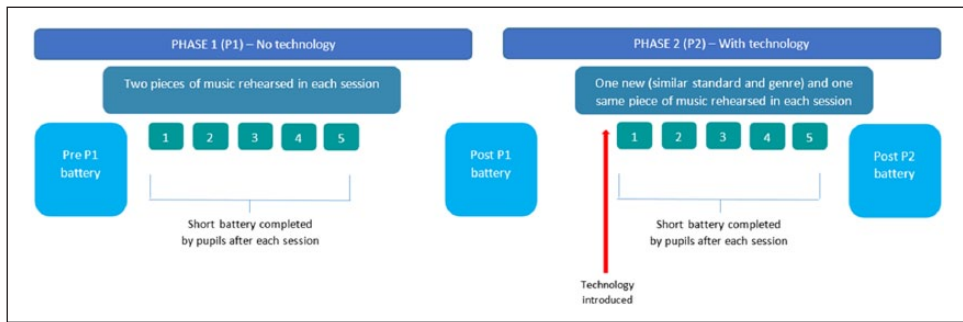
Figure 1. Research design plan showing the two phases of research.

Participants

Primary school pupils in East Sussex ($N = 28$)[3] in Years 4, 5 and 6 (age range 8 to 11 years; $M = 9.25$ years; 17 female, 11 male), taking part in a voluntary primary school orchestra club outside of normal school hours completed questionnaires. A sub-sample of pupils ($N = 8$; mean age 9.88 years; 6 female, 2 male) of mixed age, ability (1 to 5 years playing instrument), and orchestra experience (1 month to 1 year of orchestra involvement), took part in a focus group following the completion of data collection for the quantitative work. Furthermore, the orchestra conductor took part in an individual interview following completion of all questionnaire data collection.

Materials

Pre- and post-questionnaire measures. Identical questionnaires were completed by children prior to the commencement of the first session in P1 (Pre-P1), following the final session in P1 (Post-P1), and following the final session in P2 (Post-P2). Items in this questionnaire tapped into children's sense of belonging to orchestra ("I feel like I belong to orchestra"); motivation to attend ("I want to go to orchestra, so I will always try to go"); feelings of being accepted at orchestra ("I feel welcome in orchestra"); and being an important part of orchestra ("I feel my playing helps orchestra sound good"). Questions also tapped into practical issues such as their ability to keep their place in the music ("I can easily keep my place in the music and not get lost"); and knowing when it is their turn to play ("I know when it is my turn to play"). Children indicated the extent of their agreement or disagreement with the above statements using a five-point rating scale with responses ranging from "not at all" (1) to "very much" (5). In order to arrive at a score of "Overall Orchestra Engagement", composite scores for the eight items in this scale were calculated for each of the testing time points. Reliability analysis indicated good internal consistency (Cronbach's alpha at Pre-P1 $= .77$, Post-P1 $\alpha = .84$, and Post-P2 $\alpha = .86$).

Post-session questionnaires. In addition to questionnaires bookending each phase of data collection, children completed a brief questionnaire (again including quantitative ratings in response to listed questions) at the end of each orchestra rehearsal. This questionnaire tapped into the children's enjoyment of the orchestra rehearsal (three items including: "How much did you enjoy orchestra today?"; reliability across all items and all sessions, P1-Enjoy $\alpha = .88$; P2-Enjoy $\alpha = .87$), their sense of having improved and their perceived ability (three items including "How much do you feel you got better at playing the pieces today?"; reliability across all items and all sessions,

P1-Ability α = .90; P2-Ability α = .89), and in P2 a question about the usefulness of the NETEM system was also asked ("How helpful were the iPads today?"). As before, participants answered the questions using a five-point rating scale with responses ranging from "not at all" (1) to "very much" (5).

Focus-group topic guide. Focus-group questions tapped into the children's experience of orchestra including their reason for attending orchestra, activities during orchestra and what they enjoyed and found difficult about orchestra (see Appendix 1). Participants were also asked about their expectations and experiences of using the NETEM system introduced in P2.

Teacher-interview topic guide. Questions in the teacher-interview topic guide focused on the music teacher's (conductor's) perceptions of the young orchestral players' motivation for attending orchestra, the facilitators and barriers to engagement, and the teacher's own experience of using the introduced technology (see Appendix 2).

Procedure

Following study approval by the relevant internal institutional ethics committee, informed school head teacher consent for the survey data collection was sought, followed by parental permission via an information sheet and opt-out form. Once gatekeeper permissions had been gained, the survey study was explained to the young players and their informed consent sought. The children were then invited to complete the surveys during time set aside either at the beginning or the end (depending on the questionnaire type) of orchestra sessions. Prior to beginning the surveys, pupils were reminded that there were no right or wrong answers to the survey questions and that they could skip over any questions they did not want to answer, or stop altogether without giving a reason. School staff were present while the children completed the surveys, providing support with comprehension difficulties where required. Following completion of the surveys, there was an opportunity for pupils to ask any questions they had.

Separate informed parental consent was sought from the parents of the sub-sample of children taking part in the focus group. The focus group took place in an empty school classroom following an orchestra performance in the school assembly a few weeks after P2 of the research had been completed. The focus group lasted 32 minutes and was recorded using a digital voice recorder. Participating children were fully informed of the purpose and nature of the focus group, both verbally and via an information sheet, prior to its commencement. Participants gave written consent for the focus group to be audio recorded and were made aware that they could choose to end their participation at any time, for any reason, and that they could choose not to answer particular questions. The children were also assured that the content of their non-anonymised responses would not be shared with orchestra staff or players, unless they shared something that indicated a risk to themselves or others. No payment was given for taking part.

Finally, the interview with the orchestra conductor followed ethical guidelines with informed consent gained prior to the interview's commencement. The interview took place in the school hall a few weeks after P2 of the research had been completed. The interview was audio recorded and lasted 15 minutes. The focus-group and interview recordings were transcribed and then analysed by the first author following the recommended procedures set out by Braun and Clark (2006). The initial codes and final themes and sub-themes were then the subject of extensive discussions with co-authors to ensure they accurately represented the views expressed by the orchestra players and the conductor.

Findings and discussion

The findings from this mixed-methods research study are presented below, utilising both the qualitative and quantitative results. We use excerpts from the focus group with pupils and the conductor interview to illustrate the major themes and sub-themes emerging from the qualitative data, together with the results of analysis of relevant quantitative data. For the latter, a repeated-measures ANOVA was carried out to investigate general trends in the children's experiences of orchestra, while partial correlations were calculated to shed light on individual differences in terms of experiences of orchestra involvement and whether those differences were predictive of outcomes.[4] The quantitative results should be treated with caution as preliminary indications, given that the sample size for analyses across the various time points of survey data collection ranged from 13 (for comparing scores across all three time points) to 24 (for tests of scores within a single rehearsal), as a result of differences in the number of children able to attend each orchestra session. The small sample sizes restrict our statistical power to detect patterns of change or association that exist in the data, especially where these are small, but the significant results reported below do provide a meaningful starting point for understanding patterns of individual differences in children's experience of orchestra and particularly using NETEM.

Enjoyment of, and engagement in, orchestra

First, analysis of the focus group with children and of the teacher interview, together with the results of the quantitative analysis, suggest that in general the children's experience of orchestra involvement was positive from the very beginning of the study, and that this continued for its duration. The children who took part in the focus group were unequivocal about their enjoyment of orchestra and how much they valued the opportunity to play in an ensemble setting. When asked why they took part in orchestra one child simply said: "It makes me feel happy", while others elaborated by describing their enjoyment at being able to play their instrument within a group setting:

> When I play with other people I like the way that it all fits together, and it just makes me feel like: Oh, we're all playing together and I like it.

> I started learning the violin since I was five, and for about four years I've been playing alone but when I joined orchestra it just sounded so different and I felt a lot happier than playing by myself.

Here the children's emphasis is on their particular enjoyment of the musical product of playing together. The sound is "so different" to when they have practiced alone and the experience of their part fitting in with the sound of the orchestra is clearly a satisfying one. The enjoyment of playing with others and the collective sound produced in orchestral playing that the children describe mirrors the genuine interest and enjoyment that characterise intrinsic motivational orientations. This motivational orientation is recognised by the conductor who describes the children's enjoyment of collective playing and the "big sound" it produces as the primary reason for why the children take part in orchestra:

> I think for a lot of them it's just sheer love of music. I think it's the excitement of being part of something and being able to perform and be part of this big sound. Whereas some of them, their parts might actually be very simple, but they are very impressed with the collective sound that they make.

This positive experience of collective playing was also captured in the analysis of the quantitative data. Scores for Orchestra Engagement were high at each of the three time points, and

although these tended to rise slightly from the beginning of the study to the end of the study, there were no significant differences across time (Pre-P1, $M = 3.77$, $SD = .60$; Post-P1, $M = 3.95$, $SD = .66$; and Post-P2, $M = 4.03$, $SD = .65$) as determined by a one-way repeated measures ANOVA, $F(2, 24) = .705$, $p = .504$. Furthermore, when a pair-wise *t*-test was run specifically comparing aggregated session enjoyment scores taken during P1 (P1-Enjoy $M = 4.34$, $SD = .49$) to those taken during P2 (P2-Enjoy $M = 4.36$, $SD = .51$), no significant difference was found, $t(16) = -.26$, $p = .800$. These ratings ranged from 3 (a little) to 5 (very much), with one-sample *t*-tests showing that ratings for enjoyment at each session in both phases were significantly above 3, all *ps* < .001. Thus, contrary to our expectations, levels of overall engagement – as reflected in questionnaire ratings – did not appear to change with the introduction of the NETEM system in P2.

However, the questionnaire data did reveal important individual differences in enjoyment of the orchestra rehearsals. Interestingly, those who rated their rehearsal experiences most positively during P2 (P2-Enjoy) were those also showing most enjoyment during P1 (P1-Enjoy), even after controlling for perception of playing ability in P1 (P1-Ability), partial $r = .64$, $p = .007$. Furthermore, greater enjoyment of orchestra rehearsals during P2 (P2-Enjoy) tended to predict greater Overall Orchestra Engagement at the end of P2, even after controlling for their overall perceptions at the end of P1, their perception of playing ability during P2 (P2-Ability), and their rating of how helpful the NETEM system was during P2, partial $r = .683$, $p = .029$. These findings support previous research by Kokotsaki and Hallam (2007), which indicated that enjoyment of ensemble music playing is associated with greater motivation to engage further in musical activities.

Individual differences in response to the NETEM system

Both the quantitative and qualitative data suggested that children's enjoyment and perceived ability during rehearsals related to their perceptions of how useful they found the technology and their enjoyment at P2. Correlational analysis showed that children who reported particularly high enjoyment of rehearsals during P1 (P1-Enjoy) perceived the NETEM system to be more helpful during P2, after controlling for ability at P1 (P1-Ability, $M = 3.82$, $SD = .82$) and Overall Orchestra Engagement at the end of P1 (Post-P1), partial $r = .61$, $p = .047$. Interestingly, this was not true for children who reported greater perceived *ability* in P1. In fact, there was a non-significant tendency for children who reported *less* perceived ability during P1 rehearsals (P1-Ability) to perceive the NETEM system as more helpful during P2, after controlling for enjoyment during P1 (P1-Enjoy) and their perception of orchestra overall at P1 (Post-P1), partial $r = -.37$, $p = .263$. Thus, the questionnaire data suggested that those who felt most positive about the helpfulness of the NETEM system were those who previously enjoyed orchestra, but did not necessarily believe their own ability to be very good.

Importantly, although ratings of the helpfulness of NETEM in P2 were generally high ($M = 4.32$, $SD = .66$), the children who rated NETEM most highly reported significantly more enjoyment of orchestra rehearsals during P2 (P2-Enjoy), even when controlling for previous levels of rehearsal enjoyment during P1 (P1-Enjoy), partial $r = .55$, $p = .028$. Thus, in line with Charissi and Rinta's (2014) comment that digital tools can create a supportive environment for children's collaboration in music in the right conditions, rehearsals were enjoyed more by those children who experienced NETEM as helpful. This pattern was evident in the focus-group responses too. Children reported enjoying orchestra even more once the technology had been introduced, compared to without the NETEM system. When asked why they enjoyed orchestra more with the addition of the introduced technology, a number of children pointed out that that the technology had

helped them to overcome some of the barriers they had previously experienced, such as losing their place in the music:

> I think it's more fun with the iPads because it's easier and so … It's nice playing music and it's fun playing music, but not really when you lose your place, but you never lost your place with the iPads.

> It's much better with the iPads because you won't get lost because it turns the page automatically and it helps the tune stick together, so it doesn't get people going with different parts, and then you'll just know where you're going so you won't have to worry about that too much.

These extracts highlight how the introduction of the NETEM system could amplify the "fun" and enjoyment already experienced during orchestra by reducing or completely removing the distressing experience of losing one's place in the music. This in turn could enable some children to more fully engage in their part and orient themselves within the music as a whole, thus taking full advantage of the ensemble music making experience. The conductor also described how, by being able to follow their parts more consistently because of the NETEM system, many of the children had been able to engage more in collective playing, which she felt had added to their enjoyment of orchestra.

> When they don't know the part and they don't know the rhythm, then we have to rehearse it far more before we can play it collectively. When the rhythm is being shown to them, they can join in far quicker.

Together these findings reflect previous research which has shown that perceived competence in a given domain predicts greater motivation in that domain (Bandura, 1977; Schunk, 1995), as well as enjoyment (see Deci & Ryan, 2000; see Wang & Liu, 2007, for an example of this association in the domain of sport). Furthermore, Hallam and colleagues (2016), whose research showed a decline in motivation for early stage instrumental learners, have proposed that this decline in learners' motivation indicates the need for effective strategies to sustain self-belief and enjoyment. When it comes to the challenges of ensemble music making, the NETEM system may be one such strategy which can potentially help some children to increase their sense of instrumental competence and self-efficacy, and to sustain, or even increase, their level of enjoyment in musical activities and their instrument.

Certainly, the conductor felt that the introduction of the NETEM system had enabled more children to remain within the orchestra where previously many would have dropped out because they were struggling:

> There are far more children that were struggling before that are now really able to take part with the iPads. […] [The NETEM system is] useful for everybody, but for the less able it makes joining in accessible, whereas before, I think there's a few musicians there that are very new to it that might have struggled and then decided I think I'll stop and join again in a year. That does happen sometimes. […] Because they need to be able to sight-read and the iPads, from the teacher's point of view it's great because it's not deskilling them, it's not telling them the note, they've still got to read the music …

These comments from the conductor illustrate well how the NETEM system may have had a particular role in scaffolding the orchestral playing for some children – particularly those struggling to keep their place – enabling them to continue to benefit from playing in orchestra. Moreover, this extract suggests that those children's psychological need to experience competence in their environment, could potentially be met by the introduction of the NETEM system, as an optimal level of challenge was reached which did not "deskill" the child, but instead enabled them to continue to

participate in a meaningful and enjoyable way. The fact that the conductor perceived these benefits is encouraging, as it suggests that this kind of technology could plausibly be integrated by instructors into routine practice in the future (see Ifenthaler & Schweinbenz, 2013).

Technology and children's sense of belonging

Besides the perceived impact reported by some of the children on their experience of instrumental playing (e.g., sight-reading), our quantitative and qualitative results suggest that NETEM may have enabled some children to sustain their involvement in orchestra and therefore to have more experiences of group membership and belonging – factors which research indicates are likely to underpin motivation for engaging in music ensembles (Hallam, 2010; Kokotsaki & Hallam, 2007). Our findings mirror these previous findings by indicating that the children's enjoyment of orchestra is tied up with a social dimension. This is clear from the responses from children in the focus group which revealed the high value they placed on the opportunity that playing in orchestra gave them to be part of a group, to develop new relationships with their peers, and ultimately to belong.

> I think it really helps interact with other people as well. Because I've got this boy in my class and I don't get on with him very well, but when we're in orchestra we can just play together and just forget about everything.

> There's a boy in another class that I don't really know, and when I joined orchestra I now know him and now we're in a band together, where before I wouldn't really know him.

In particular, these extracts highlight the children's experience of orchestra as a transformative, liminoid space (Schechner, 2013), where new ways of being with one another can be established, while new friendships, as well as the possibility for new musical activities, can be pursued. This inclusive community provides ample experiences of belonging and acceptance, as the orchestra works as one entity combining efforts to produce together the "big sound" the children so love.

The analysis of survey data supports these findings with results indicating that higher ratings of enjoyment of orchestra rehearsals during P2 (P2-Enjoy) predicted scores on a specific item in the final questionnaire that tapped into sense of belonging ("I feel like I belong to orchestra"), controlling for prior rehearsal enjoyment during P1 (P1-Enjoy), partial $r = .60$, $p = .019$. As noted above, we cannot make definitive claims about NETEM having overall benefits in increasing children's engagement with orchestra (which was high from the start). However, our results have shown that at least some of the children reported particular benefits from using NETEM, which in turn appeared to keep them positively engaged with orchestra. Indeed, since higher ratings of enjoyment of orchestra during P2 (P2-Enjoy) were predicted by perceptions of the NETEM system as being more helpful, as noted above, engaging with the introduced technology could evidently have led some children to keep playing in the ensemble and thereby experience more social engagement. As one child expressed in simple terms:

> When we got the iPads it just … I wanted to stay and carry on playing music.

Practicalities of engaging with the NETEM system

A great number of practical advantages to the introduced technology were cited by both the children and the conductor, corresponding to Manzo's (2014) observation that musical development can be enhanced by removing some of the many layers between the musician and the given musical

task. The advantage most commonly mentioned by the children was that playing music with the NETEM system meant that because their place in the music was indicated via a highlighted bar, they were less likely to lose their place in the music – an experience that had clearly been a frustrating and somewhat stressful experience beforehand:

> I think it's easier with the iPads, because I used to lose my place all the time and I used to think: Oh, hang on a minute, where am I? And I just used to lose it. But now that we have the iPads, it's highlighted in green, and I think: Oh, well, I've lost my place. Oh, here it is! Because I immediately can find it again.

The experience of disorientation and lack of agency was palpable in such descriptions from children of getting lost during orchestra rehearsals when they used paper music notation. Interestingly, their descriptions of being able to find their place with the NETEM system suggest greater experiences of control and agency: "I immediately can find [my place] again". With the introduced technology, children who previously may have relied on someone else pointing out where they should be in the music, could swiftly and independently orient themselves and engage with the orchestra again. Existing theory and research suggest that the experience of increased agency reported by children is likely to impact on feelings of competence and may also satisfy the psychological need of autonomy, as outlined by SDT (Ryan & Deci, 2000).

A further common problem that the children said had been overcome since using the NETEM system was the fact that very often when they were using sheet music the paper would fall off the stand, whether because of a draft or a passing person. Although making copies and using stand clips can of course help with this problem, our results show a clear contrast between the experience of working with NETEM and the reality of paper-based music rehearsals with an ensemble of young children. The children also talked about how the nuisance of having to turn over a page of music whilst playing had been avoided since the NETEM system had been introduced:

> Well, sometimes it [turning the page] can be like a little bit of like a hassle. You have to like turn the page, and then play. 'Cause like if the piece was supposed to go duh, duh, duh, duh (sung ascending with a steady beat) and you would have to do duh, duh, [pauses and mimes turning the page], duh, duh [laughter]. 'Cause like you would have to do something in the middle of the piece sometimes.

These issues were also recognised by the conductor, who identified the disruption caused by these issues when using sheet music, and felt that using the NETEM system allowed these challenges to be overcome, letting the children focus on the challenge of instrumental playing in a group setting.

Indeed, both the conductor and children commented that since the introduction of the NETEM system, synchrony within the orchestra had increased, allowing the conductor to introduce more difficult pieces and the orchestra to successfully tackle those pieces with confidence:

> Conductor: The number of times we end up stopping [during rehearsals] because we're all not together are few and far between now. [The NETEM system] makes a big difference. […] I think we'd still get there, but it would be much harder to get there, take much longer. So [the NETEM system] will definitely enable us to learn new pieces and more difficult pieces.

> Child: We've been doing a lot of different songs lately and … we do a lot harder ones now we've got the iPads.

Limitations and directions for future work

Despite the rich insights into young orchestral players' experiences of using the NETEM system, we cannot assume that these experiences would generalise to all young orchestral players using the NETEM system. Indeed, the quantitative data clearly point to individual differences in experiences. Furthermore, whilst the longitudinal nature of this study gives some preliminary weight to possible causal interpretations, the small sample size means that caution should be observed when interpreting the results of the quantitative analysis of survey data. Additional longitudinal research with larger samples of ensemble musicians is now needed to systematically examine the extent to which the NETEM system can enhance the experience of ensemble performance and to test pathways between experiences of self-efficacy, agency, intrinsic motivation and belonging, which our results suggest may underpin positive outcomes.

In addition, a research design with multiple, well-matched ensembles that are randomly allocated to using NETEM or traditional systems (i.e., experimental and matched control groups) would be helpful for future evaluation of NETEM. With just one ensemble available for this preliminary development and evaluation work, we must acknowledge that any overall differences between the traditional and NETEM phases could be related in part to the greater experience and ability as well as to the inclusion of a new piece of music. However, this does not detract from the participants' direct comments on their experience of using NETEM, nor from the analysis of individual differences in their response to the NETEM system.

A further limitation of the present study is that our quantitative measures relied on children's self-report, which means that the possibility of shared method variance, informant bias, and socially desirable responding by participants cannot be ruled out. In order to increase validity, alternative measures should be included in future research, such as those made through detailed observation methods. For example, video recordings of rehearsals can be used to capture any changes in ensemble playing (e.g., participation of participants, expressed frustration) before and after the introduction of the NETEM system.

Additionally, whilst Braun and Clark's (2006) procedures were followed in terms of our analysis of the focus-group and interview recordings, we did not have participants complete member checks (Lincoln & Guba, 1985) to ensure accurate representation of their views. Similar future research should include member checks in order to enhance rigor and credibility. However, as the contributions of the children and orchestra conductor were very concrete and self-explanatory, and required minimal interpretation, we do not think that the internal validity has been threatened.

Additional factors related to children's ability to engage in ensemble music making (e.g., sight-reading ability, instrument grade/level, length of time in orchestra) would extend our understanding of what existing individual differences explain the variance observed in participants' responses over time, and how they interact with orchestra experiences and perception of the usefulness of the technology introduced. It is likely that there are constraints on the impact of the NETEM system for learner instrumentalists such that the system is particularly salient at a certain stage in their learning and that the benefits of the system may change beyond certain stages or cease altogether. These constraints must be examined by systematically comparing ensemble groups of differing levels of skill and experience in future research to determine what level of learner experience/skill is optimal for the benefits of the system to be enjoyed.

The way in which individual differences among musicians translate into a wide range of outcomes should also be studied carefully. For example, we already know that individual differences in achievement goal motivation are associated with different types of practice behaviour (Miksza, 2010). Thus, future research could fruitfully focus on more elaborate analyses of individual differences in responses to technology such as NETEM, covering not only enjoyment of and persistence

with ensemble music making, but also individual musical development and practice behaviour. Moreover, all of these factors need to be considered within sociocultural context, given that, as well as school instructional approaches, family characteristics, socioeconomic status, gender, and culture are all likely to relate to children's expectations, beliefs, goals, values, and behaviours in the musical domain (see Hartley & Porter, 2009; Hawkinson, 2015; Kinney, 2010; McPherson & O'Neill, 2010).

Finally, the networked system was not without its own weaknesses in terms of usability and creativity (Eldridge et al., 2016). Future work should include more refined approaches to human–computer interaction and in particular the development of wireless tools for direction, and other strategies to enable conductors to lead the ensemble music experience hands-free and thus in a more expressive way than is currently possible. Further work should also refine the notation and display systems, including accessible settings to control the degree of scaffolding provided to musicians as they increase in confidence (e.g., how much signalling of position in the music is provided to ensemble players). The development of "augmented" notations can also be explored; this would build on standard notation but would make a range of wirelessly synchronised musical cues more widely accessible (for example colours and other graphics to indicate texture, dynamics and timbral changes). This would enable the affordances of contemporary tablet technology to be fully harnessed to the needs of contemporary music ensembles in a wide range of community settings – including its potential as a tool for inclusive music education for pupils with special educational needs (SEN) (Burnard, 2007; Farrimond, Gillard, Bott, & Lonie, 2011; Kleiman, 2004) – thus contributing to Hallam's (2010) vision of a supportive and flexible environment capable of sustaining creativity and self-expression.

Conclusion

In summary, findings from analysis of data from the qualitative and quantitative strands of work highlight how the NETEM system may have scaffolded some children's orchestral playing by reducing barriers to engagement, including keeping time and synchrony, thereby enhancing their enjoyment of orchestra and ultimately leading to more social engagement. Furthermore, this experience appeared to be especially true for those children who had previously enjoyed orchestra but who had reported less perceived ability prior to the introduction of the NETEM system. As described above, we believe our results set an agenda for future research to build on these encouraging findings. Such research will be crucial if the potential of networked systems for enhancing access to and retaining the engagement of young people in ensemble playing is to be realised.

Funding

Notes

1. For further information on the NETEM system visit http://netem.org.uk/
2. Over the course of the funded project, NETEM was tested with primary and secondary school pupils, a professional classical chamber ensemble, an amateur contemporary music group, and an experimental rock group, to explore its usefulness in a range of settings. The ongoing development of the software through computer coding occurred in parallel with this testing, enabling technology to be developed in tandem with feedback from both adult and child users.
3. Note that there was considerable variability in N from session to session depending on students' availability.

4. The partial correlations tested whether differences in children's responses to questions at one time point (predictors) were statistically associated with subsequent responses to other questions (outcomes), after controlling for other variables that could potentially be playing a role (e.g., earlier scores on the outcome measures).

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Appendix 1. Focus-group topic guide.

Topic Guide		
Theme	Research question	Actual question
Experience of orchestra	Reason for attending, Activities during orchestra, Enjoyment, Difficulties	Why do you play in orchestra? What makes you come to orchestra every week? What kinds of things do you do at rehearsals? What do you enjoy the most about playing in orchestra? Why? What is the best bit about orchestra? Why? Would you recommend playing in an orchestra to other young people? Why? Is there anything you don't like about orchestra? Can you tell me about that? What's the most difficult thing about playing in orchestra? Is there anything that helps to make that better/less difficult?
Experience of using NETEM during orchestra rehearsals	Expectations, Experience, Perceived improvement	How did you feel when you heard that you would be using iPads instead of sheet music? What has it been like to use the iPads? Do you prefer to play in orchestra with the iPads or without? Why? What is the best thing about using the iPads? What is the best thing about using sheet music on stands? How could the iPads be better? Do you think your playing during orchestra has changed since the iPads were introduced? If so, how has it changed?

Note. NETEM = Networking Technologies and the Experience of Ensemble Music Making.

Appendix 2. Teacher-interview topic guide.

Interview with music teacher/orchestra conductor

Theme	Research question	Actual question
Motivation	Pupil motivation for taking part, Pupil enjoyment/difficulties	What motivates pupils to take part? What brings them back week after week to each session? What do they like best and least about the sessions?
Engagement	Pupil engagement (pre-technology), Barriers to pupil engagement	Prior to the introduction of the NETEM system did you find that pupils could join in and fully engage in the orchestra? What are the main challenges/barriers to participating fully in the orchestra for pupils? How were these barriers tackled or overcome prior to the introduction of the NETEM system?
Experience of using NETEM technology	Teacher and pupil expectations prior to introduction of technology, Experience of technology, Benefits and difficulties of technology	How did you feel about the technology being introduced? What were your hopes, fears, expectations? How do you think the pupils felt? Can you tell me a bit about your experience of using the technology? How did it work? What were the difficulties (if any)? What were the benefits (if any)? Can you tell me what difference, if any, the introduction of the technology has had on pupils' ability to join in and engage fully in orchestral playing?

Note. NETEM = Networking Technologies and the Experience of Ensemble Music Making.