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The Pedagogical Use of Visual Feedback for Enhancing Dynamics in Higher Education Piano Learning and Performance

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Abstract: Research on technology-based learning and teaching has demonstrated evidence of its relevant role in music education. However, the application of technology to studio-based instrumental learning and teaching remains a relatively under-researched area. The article draws on findings from a recent exploratory study (HAMOND, 2017) which included fieldwork in Brazil. The aim of this study was to investigate the nature and potential pedagogical use of technology-mediated feedback in a higher education piano studio. Participants were one student-teacher dyad plus the researcher (the first author) with the dyad working on a memorised movement of a classical sonata of the student's current repertoire. The technology system involved a digital piano connected to a laptop computer running Digital Audio Workstation (DAW) software via Musical Instrument Digital Interface (MIDI) interface, and an additional computer screen. Three data sets were collected: videoed piano lessons (n = 2), semi-structured interviews with participants after each piano lesson (n = 4) and technology-generated MIDI data through the use of DAW software. Qualitative data analysis (QDA) involved a multi-methods approach. Research outcomes demonstrated how new digital technology can improve accessibility to aspects of advanced musical behaviour and learning that are often outside the individual's conscious awareness. The use of new digital technology can also optimise traditional pedagogical approaches in one-to-one piano studios, since it is likely to make the lesson foci clearer and the learning process more efficient.

Keywords: Piano pedagogy; technology-based learning; visual feedback.

O uso pedagógico de feedback visual para aprimorar a dinâmica no aprendizado e na performance de piano no ensino superior

Resumo: As pesquisas sobre ensino e aprendizagem musical com tecnologias digitais tem demonstrado evidências do papel relevante da tecnologia na educação musical. No entanto, a aplicação de tecnologia no contexto específico do ensino e aprendizagem instrumental é uma área pouco explorada onde pesquisas ainda são necessárias. Este artigo baseia-se nos resultados de um estudo (HAMOND, 2017) com uma pesquisa de campo conduzida no Brasil. O objetivo deste estudo foi investigar a natureza e o potencial pedagógico do uso de *feedback* mediado por tecnologia em aulas de piano de nível superior. Um par professor-aluno de piano e a pesquisadora (a autora deste capítulo) participaram desta pesquisa trabalhando um movimento de sonata de clássica previamente memorizado de seu próprio repertório. O sistema tecnológico foi composto por um piano digital conectado a um computador portátil usando software Digital Audio Workstation (DAW) através de interface Musical Instrument Digital Interface (MIDI) e uma tela de computador adicional. Três fontes de dados foram coletadas: observação de aulas de piano registradas em vídeo (n = 2), entrevistas semiestruturadas com cada participante gravadas em áudio (n = 4) e os dados MIDI gerados por tecnologia e gravados através do uso do software DAW. A análise qualitativa de dados incluiu uma abordagem multi-método. Os resultados da pesquisa também demonstraram como a nova tecnologia digital pode melhorar a acessibilidade a aspectos avançados do comportamento musical e do aprendizado sobre os quais muitas vezes o indivíduo não tem consciência. O uso de tecnologia digital também pode otimizar abordagens pedagógicas tradicionais de aula de piano, pois permite que o foco da aula fique mais claro e o processo de aprendizagem seja mais rápido.

Palavras-chave: Pedagogia do piano. Aprendizagem mediada pela tecnologia. Feedback visual.

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Feedback is central in enhancing learning. Wiener (1961: 6) was the first author to use the concept of feedback in the field of cybernetics; he explained how feedback forms a loop for learning "[…] the difference between this [a given] pattern and the actually performed motion is used as a new input". Feedback has also been reported in work in the field of motor control and learning in sports (MAGILL, 1989. SCHMIDT; LEE, 2011). Two types of feedback appear as central: Knowledge of Results (KR) and Knowledge of Performance (KP). KR and KP are defined as the information provided by the coach (or tutor) to the learner about the outcome and nature of the learner's movement, respectively (SCHMIDT; LEE, 2011).

The impact of feedback in learning and teaching has been reported in various classroom studies (HATTIE; TIMPERLEY, 2007. HOUNSELL, 2003). Effective feedback must be "clear, purposeful, meaningful, and compatible with students' prior knowledge and [needs] to provide logical connections [which] relate to specific and clear goals" (HATTIE; TIMPERLEY, 2007: 104). Several research studies have also reported the crucial role of feedback in different contexts of music learning and teaching: such as in the conventional piano studio (KOSTKA, 1984. SIEBENALER, 1997. SPEER, 1994); and in one-to-one higher education (HE) instrumental learning (BRYAN, 2004. BURWELL, 2010. Cf. CREECH; GAUNT, 2012 for an overview). Technology-mediated feedback has been reported to enhance learning: in music education using information and communications technology (ICT) (HIMONIDES, 2012); in HE music production studios (KING, 2008); in the music classroom (SAVAGE, 2007); and in technology-based learning in singing studios (WELCH, 1983, 1985a, 1985b. WELCH; HOWARD; HIMONIDES; BRERETON, 2005).

A master-apprenticeship model has been identified in one-to-one instrumental and singing learning in several studies (HALLAM, 1998) "where the dominating mode of student learning is imitation" (JØRGENSEN, 2000: 68). The supportive use of technology in one-to-one instrumental learning has been highlighted "as a medium of transformative change" (CREECH; GAUNT, 2012: 701) towards "student reflection, autonomy [and] motivated, self-directed learning" (CREECH; GAUNT, 2012: 703). However, there has been little research on the use of technology in HE piano studios, especially on the use of additional visual feedback. This paper presents selected findings of a study (HAMOND, 2017); it focuses on the application of additional feedback generated by a new technology system in one example of an HE piano studio case study.

Intrapersonal feedback in instrumental and singing studios. Feedback in instrumental and singing learning and teaching is both intra- and inter-personal. Intrapersonal feedback is related to the feedback that happens inside an individual and involves the individual sensory system. Intrapersonal feedback in piano learning and playing mainly encompasses auditory (BANTON, 1995. FINNEY, 1997), visual (BANTON, 1995. BISHOP; GOEBL, 2015, 2018) and proprioceptive (BROWN; PALMER, 2012. WÖLLNER; WILLIAMON, 2007) feedback, and internal processes of the individual (ACITORES, 2011. DAMÁSIO, 2000. HALLAM, 2001. NIELSEN, 2001).

The role of auditory feedback has been investigated in several studies. This research suggested that an absence of auditory feedback can interfere with piano sight-reading and performance of unfamiliar pieces but cannot disturb well-known performances of memorised piano pieces (e.g. BANTON, 1995. FINNEY, 1997. FINNEY; PALMER, 2003. WÖLLNER; WILLIAMON, 2007). The role of proprioceptive feedback alongside auditory feedback seems to be essential for the recall of learned unfamiliar melodies, which implies auditory-motor associations in piano playing (BROWN; PALMER, 2012. HALWANI; LOUI; RÜBER; SCHLAUG, 2011. MOORE; SCHAEFER; BASTIN; ROBERTS; OVERY, 2016). Although several studies have proposed the crucial role of visual feedback in piano sight-reading for untrained pianists (BANTON, 1995) and also in piano duet synchronisation (BISHOP; GOEBL, 2015, 2018. GOEBL; PALMER, 2009), the role of visual feedback in piano learning and playing needs further investigation. Intrapersonal feedback also encompasses other internal mechanisms of an individual. These internal processes encompass the conscious-awareness state of the individual (ACITORES, 2011), the sense of self (DAMASIO, 2000), metacognitive knowledge (HALLAM, 2001), and self-regulatory skills (NIELSEN, 2001). Intrapersonal feedback happens internal to the individual in both piano learning and during piano playing.

Interpersonal feedback in piano learning and teaching. Interpersonal feedback happens alongside intrapersonal feedback in piano learning; it can occur between the individual and an external source, such as a teacher, their peers, their family, or a type of technology. Interpersonal feedback is one of the behaviours which were observed in one-to-one instrumental and singing learning and teaching (BENSON; FUNG, 2005. BURWELL, 2010. HAMOND, 2013a, 2013b. SIEBENALER, 1997). The teacher customarily delivers feedback to the student in order to provide information on the student's performance; it is usually provided to the student through general (positive, negative or ambiguous) and specific feedback.

Interpersonal feedback between the teacher and the student in piano studios can be verbal and non-verbal (BENSON; FUNG, 2005. BURWELL, 2010. HAMOND, 2013a, 2013b. SIEBENALER, 1997) linked with an aspect of musical performance, such as dynamics, articulation, or tempo (HAMOND, 2013a). Types of verbal feedback that have been reported in these studies as specific are offered in the form of giving instructions, providing information, and questioning. General verbal feedback involves giving positive, negative or (in some instance) ambiguous feedback. Another observed teacher verbal behaviour encompasses off-task comments (BENSON; FUNG, 2005. BURWELL, 2010. HAMOND, 2013a, 2013b. SIEBENALER, 1997). Types of non-verbal feedback can take the form of (a) the teacher playing, singing, or modelling, (b) the teacher imitating the student's playing, and (c) making hand gestures or body movements, such as conducting and tapping the pulse (BENSON; FUNG, 2005. BURWELL, 2010. HAMOND, 2013a, 2013b. SIEBENALER, 1997). Other general non-verbal feedback involves smiling, laughing, nodding, shaking, as well as other facial expressions.

Although the individual lessons are customized to improve specific music performance skills of the students, teachers and students reported different perspectives on the priorities for learning in piano lessons (HAMOND, 2013a). As such, it may be that externally sourced information such as provided by technology might enhance learning foci and make teachers and students more aware of their teaching and learning goals, respectively.

Technology-mediated feedback in instrumental and singing studios. Interpersonal feedback can also occur between technology and an individual in instrumental and singing learning and teaching, i.e., the student-teacher dyad. Various types of technology have been used in instrumental and singing studios: the metronome, audio and video recording and playback, computer feedback, and real-time visual feedback (RTVF) (cf. HIMONIDES, 2012 for an overview). The application of technology in music education settings was shown to benefit higher education singing students (WELCH *et al*., 2005) and to possess both similar and different characteristics of non-technology-based music education settings (SAVAGE, 2007). In music production studios, technology-based learning is reported to have contributed to a more collaborative environment in educational settings (KING, 2008).

The use of technology in the form of RTVF in instrumental and singing learning and teaching has received increasing research attention (BRANDMEYER, 2006. SADAKATA; HOPPE; BRANDMEYER; TIMMERS; DESAIN, 2008. WELCH, 1983, 1985b. WELCH *et al*., 2005). RTVF has been investigated in tapping (SADAKATA *et al*., 2008) and percussion imitation tasks (BRANDMEYER, 2006) and in technology-based higher education singing studios alongside the teacher (WELCH *et al*., 2005).

A study which investigated the use of RTVF by musically trained participants in imitation and perception tasks of short rhythms suggests that RTVF can improve imitation of dynamics (loudness), however, it does not facilitate the imitation of timing patterns, and does not seem to affect the transfer of learning, such as from imitation to perception (SADAKATA *et al*., 2008). There is an effect of different visual representations during RTVF in a drum studio during a task involving audition and motor skills: some participants felt distracted by the visual feedback and other participants reported the visual feedback was meaningful to them supporting their learning (BRANDMEYER, 2006). Different feedback display options offered by the technology, such as spectrograms, videos of student performances, frequency and singing tract displays, appeared to facilitate discussion between teacher and student on specific aspects of singing, since data was recorded, saved, and available to be played back through this specific software (WELCH *et al*., 2005). These previous studies suggest that the use of visual feedback in real-time can improve specific aspects of the performance (e.g. dynamics, singing aspects), but that it depends of the level of engagement of the individual, if the visual feedback is meaningful to the individual, and the nature of the pedagogical approach of the teacher.

The application of digital technologies has been investigated in piano performance and improvisation (FRANÇOIS; CHEW; THURMOND, 2007. MCPHERSON, 2013). In one study, RTVF in the form of a multicolour-system was reported to have beneficial effects on pianists since it has the potential to "provide rich visual feedback to assist the performer in interacting with more complex sound mapping arrangements" (MCPHERSON, 2013: 152). RTVF in the form of piano roll notation had assisted pianists in piano improvisation by providing "the performer with instantaneous and continuous information on the state of the system" (FRANÇOIS *et al*., 2007: 278).

The application of musical instrument digital interface (MIDI) technology has been used as a measurement means for musical performance practice assessment (HIMONIDES, 2012). In this way, MIDI technology encompasses data with regard to "every stroke on the keyboard" (HIMONIDES, 2012: 450) including the correspondent pitch of each played key or note, the length of time for which each key or note was pressed and released, and the velocity with which the key or note was pressed (HIMONIDES, 2012). In addition, similar parameters for the action of the pedals can also be measured.

In conclusion, there is a potential use of technology in piano studios where many aspects of musical performance can be worked on and also be associated with technology-related data, such as piano roll notation, spectrograms, video recording of performance, making the learning foci clearer between the teacher-student dyad.

Technology-based piano learning. Several studies have investigated the perspectives of teachers, pianists and students on the use of different types of technology in piano learning: audio recording (ZHUKOV, 2010), video recording (CAREY; GRANT, 2015. DANIEL, 2001), MIDI protocols and piano roll visualisation (RILEY, 2005. TOMITA; BARBER, 2008), and instructional media (BENSON, 1998). Most of this research was based on perspectives rather than on the actual application of a technology-based learning environment.

In piano learning and teaching, teachers customarily provide feedback to advise students on how to improve their playing for particular musical performance parameters such as articulation, dynamics, tempo, or pedalling (e.g. BRYAN, 2004). Studies have investigated musical performance parameters for different purposes: (a) analyses of musical performances (BERNAYS; TRAUBE, 2014); (b) examining relationships between musical parameters such dynamics and timing (REPP, 1996); (c) understanding the piano learning processes (CHAFFIN; IMREH, 2002. MIKLASZEWSKI, 1989); and (d) investigating the criteria used when assessing piano performances by adjudicators (THOMPSON; WILLIAMON, 2003. THOMPSON; DIAMOND; BALKWILL, 1998).

Analyses of musical performances have been conducted through technology-generated MIDI data which seemed to be related to certain musical performance parameters such as timing and dynamics (REPP, 1996), and timing, dynamics, articulation, and pedalling (BERNAYS; TRAUBE, 2014). Such analyses were possible because of the technology-generated data derived from the application of MIDI protocols to computer-controlled pianos. By using these types of technology, piano performances can be assessed through technology-generated MIDI data by relating them to selected musical performance parameters. This can be done for qualitative analysis, such as MIDI note colours, sizes, and key velocity numbers, or for quantitative analysis, through inter-onset-interval (IOI), key overlap time (KOT), and key detached time (KDT) (BRESIN; BATTEL, 2000. PALMER, 1989) variables which reveal data about pianist keyboard and pedal activity (BRESIN; BATTEL, 2000. PALMER, 1989).

The current paper presents an illustrative excerpt from a research project that explored the pedagogical uses of technology-mediated feedback in HE piano studios in Brazil (HAMOND, 2017). This paper focuses on the outcomes of an example case study on the pedagogical use of post-hoc visual feedback for learning enhancement of dynamics in an HE piano studio.

Method

An action case study approach (BRAA; VIDGEN, 1999) was used in this study. This is a hybrid methodology, encompassing characteristics of both a case study (STAKE, 1995. YIN, 2014) and action research (KEMMIS, 1993). The case study in this research was an HE piano learning and teaching student-teacher dyad. The characteristic of this action case study is the application of a technology system to explore its pedagogical uses with the teacher and student. An action case study was considered appropriate in order to investigate "in-context research on a small-scale and structured intervention" (BRAA; VIDGEN, 1999: 44).

Participants. The study received ethical aproval from the UCL Institute of Education, University College London and followed British Educational Research Association (BERA, 2011) guidelines. Participants received an information leaflet about the nature and confidentiality of the study, and signed consent forms as agreement to take part. Participation was voluntary with the reimbursement of travel expenses. Three dyads participated in the original study (HAMOND, 2017); however, the current paper is focused on the research outcomes of one dyad only. This was a student-teacher piano dyad in an HE learning and teaching setting, alongside the first author who operated the technology system during the lessons. The criteria for participation was: (a) to be in HE; (b) to be working together on a regular weekly basis within the context of one-to-one lessons; and (c) to have worked on a memorised piece from their current repertoire. The piano student was enrolled in a higher education institution in Brazil in a music education undergraduate programme. Teacher-student dyad had worked together on a weekly basis for two years. They chose to work on the second movement of a classical sonata for this study.

At the time of the study, January 2014, the student was a second instrument HE piano student, and the teacher was an experienced pianist and HE piano tutor. The student was male and 25 years old; the teacher was female and 51 years old with 15 years of overall piano teaching experience. The student reported having previous experience in playing a digital piano and in using Digital Audio Workstation (DAW) software for music studio production purposes. Both participants reported not having used this type of technology system in piano learning.

Data collection. Three sources of data were collected in this study: video recordings of piano lessons (n = 2), post-lesson audio recorded interviews with the teacher and the student separately (n = 4), and technology-generated MIDI data with Cockos' Reaper DAW software (http://www.reaper.fm). Two layers of materials were used: one related to the data collection itself (video observation and interview data) and the other related to the technology-related MIDI data recorded when using DAW software.

Video observation was used to capture verbal and non-verbal behaviours of participants, whilst interview data captured perceptions. Two digital cameras (SONY HDR-CX280E handy cam) and one voice recorder (Zoom H1 Handy Portable Digital Recorder) were used to collect video observation data and interview data, respectively. Video data was recorded to capture both the interaction between the participants and what was happening on the additional PC screen placed on top of the digital piano and in front of the participants (see triangles positioned in Fig. 1).

Technology-generated MIDI data was generated in real-time by recording the data on DAW software. MIDI data with piano roll visualisation corresponding to the participant's piano performances could be accessed and re-visited posteriori (post-hoc) during the piano lesson by playing back the recorded data. The technology-generated MIDI data were collected via a digital piano Yamaha Clavinova CVP-403 connected to a laptop computer SONY VAIO running Cockos' Reaper DAW software with piano roll screen option via a MIDI interface, i.e. two MIDI cables, THE SSSNAKE SK366-3-BLK MIDI; MIDISPORT 1X1 USB, and one additional PC computer screen LG FLATRON W1943SE, and a VGA cable to connect the laptop computer and the additional PC screen.

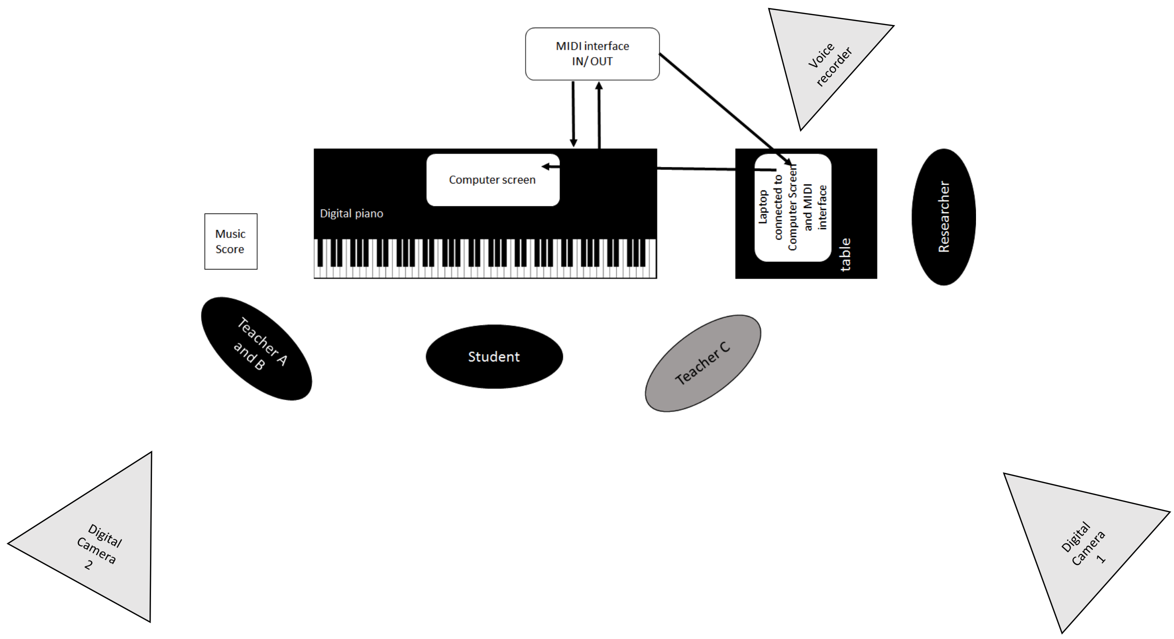

Fig. 1: Overhead view of the positions of materials and participants including data collection equipment (HAMOND, 2017: 160).

Fig. 1 shows an overhead view of the approximate position of the materials and participants, including the equipment which was used for data collection such as a voice recorder, digital cameras, and the set up for the application of technology-mediated feedback. The choice of DAW software was made because it can record not only audio data but also MIDI data generated through technology by teacher and student participants performing their chosen piano pieces. This technology-mediated feedback system provided both a recording and playback of the performance-related data embracing the keyboard and pedals activity of the teacher or student.

Data analyses. A multi-methods qualitative data analysis approach was adopted. Video and interview data were analysed thematically (BRAUN; CLARKE, 2008). Video data were also analysed by looking at the microstructure analysis of the musical behaviours, as suggested when using the Study Your Music Practice (SYMP) software by Demos and Chaffin (2009). Technology-generated MIDI data was analysed qualitatively through piano roll visualisation in terms of MIDI note sizes, asynchronies, colours, and key velocity numbers. The video and interview data were analysed using the computer assistive qualitative data analysis (CAQDA) software NVivo10 QSR International (http://www.qsrinternational.com/what-is-nvivo). The use of CAQDA software assisted in organising and managing the video and interview data supporting the data analyses (FLICK, 2009).

Video data permitted the observation of verbal and non-verbal behaviours of participants, as well as musical behaviours (e.g. playing when the data was recorded and listening and/or seeing when the recorded data was played back). Interviews allowed the researcher to understand the perspectives of each participant on their experiences about this technology-based learning setting. Technology-generated MIDI data allowed the recording of both keyboard and pedal activities when the participants played the digital piano. Triangulation of the three data sources and analyses assured trustworthiness (GUBA, 1981. SHENTON, 2004).

Procedure. The student-teacher dyad described here chose to work on the second movement in G major of the Mozart Piano Sonata No. 16 in C major, K. 545, over two piano lessons. There was an interval of 4 days between the lessons. Each lesson lasted just over an hour. Although the student had memorised the piece, the music score was available in the piano lessons, and mainly used by the teacher when she was following the student's performance. While several aspects of the piano learning and performance were worked on in the lessons, here the article focuses on lesson 2 where the dyad worked on the improvement of dynamics and dynamic balance between right and left hands with the application of a new technology system facilitated by the first author.

Whilst participants played the piano, technology-generated MIDI data were recorded on the Cockos' Reaper DAW software. Data were recorded, saved, and were also available to be played back at any time in the lesson by using the same software. These data combined recorded performances and their visual representation through a piano roll form so that the lesson focus at that point in the lesson could be on listening and/or seeing the data recorded on the DAW software. This technology-generated MIDI data could be played back whilst the student was able to listen and see what was happening on the screen and not playing the digital piano; this made the focus at that point in the lesson on listening and seeing from a similar perspective that the teacher usually takes.

Each piano lesson was followed by semi-structured interviews conducted separately with the student and teacher. Four interviews were held in total for the two lessons. The interviews lasted between 45 and 70 minutes (Table 1). The first interview focused on the participants' background and their experience in using the technology system in the first piano lesson. The second interview explored the experience of participants in using the technology system by comparing their perspectives and focusing on similarities or differences between the first and second piano lessons.

Lesson 1 (duration)	Lesson 2 (duration)	Interview 1 (duration)	Interview 2 (duration)
1h13min	1h04min	T = 1h08min	T = 43min
		S = 1h04min	S = 43min

Table 1: Duration of each lesson and interview by each participant where T stands for the teacher and S stands for the student (adapted from HAMOND, 2017: 162)

Perspectives of the teacher and student concerning their learning priorities were also investigated. Although the teacher-student dyad had worked together for more than two years, their learning and teaching priorities did not converge (in line with the questionnaire findings in the pilot study which ranked and compared such responses (HAMOND, 2013b). For this case study, the teacher aimed to teach the student to listen to themselves whilst performing, focusing on the improvement of technique, phrasing, motor control issues, touch and tone quality, as well as a sense of harmony and tonality. On the other hand, the student aimed to learn about enhancing music style and playing musically.

Results

Pedagogical uses of visual feedback in an HE piano studio. In this case study, the teacher and the student were engaging with and incorporating technology-mediated feedback into their lessons. However, there was apparent anxiety as to how the lesson would be conducted, and what musical parameters the technology could inform. The student seemed very interested in technology and was already familiar with the DAW software used in the lesson. The prior engagement of this student with DAW software seemed to make the teacher feel more confident about the applied technology in the lessons. In this sense, the student assisted the teacher in establishing the relationship between what was being shown on the computer screen and the musical notation on the score. This might also have helped the teacher to be less anxious about the application of technology in the lessons. Both teacher and student in this case study not only incorporated the technology in lessons but were also willing to explore its application in a piano studio. They also found their own ways of applying the technology and supporting the learning and teaching of selected musical performance parameters in order to improve student performance of specific excerpts of the chosen piano piece.

Technology-mediated feedback could be used pedagogically to enhance specific aspects of the music performance in any of the four main modalities: real-time visual feedback, post-hoc visual feedback combined with auditory feedback at original tempo, post-hoc visual feedback combined with auditory feedback at a slower tempo, and post-hoc visual feedback only, for specific aspects of the music performance. In this case study, the teacher-student dyad used post-hoc visual feedback on silent mode for enhancing dynamics and dynamic balance of an excerpt of the chosen repertoire. The lesson focus varied in musical performance parameters for three areas: music (notation), performance (e.g. articulation, dynamics, timing), and technology (e.g. MIDI note colours, sizes, and key velocity numbers).

Real-time visual feedback (RTVF) was available when one or both participants played the digital piano whilst the technology-generated MIDI data was being recorded on the DAW software. In this study, the student-teacher dyad did not appear to have used RTVF systematically with a clear lesson focus in their piano lessons. However, the student demonstrated having used RTVF for specific aspects of his performance as self-study, such as for enhancing articulation of the left hand when playing Alberti bass.

Post-hoc visual feedback in normal mode, which is combined with auditory feedback, was available to participants when the previously recorded technology-generated MIDI data were played back to the participants alongside the piano roll visualisation. This meant that participants could not only listen to the performances, but also see the piano roll visualisation corresponding to their piano performances. The student-teacher dyad used post-hoc visual-auditory feedback for specific lesson foci related to articulation in lesson 1 and on dynamics in lesson 2.

Overall, participant perspectives on the use of post-hoc auditory feedback seemed to be unanimously positive. Participants agreed that such additional feedback was beneficial since students were solely listening, rather than playing and listening at the same time. This contrasts with what was reported for the application of RTVF where only the student used it for monitoring this playing whilst the teacher did not seem to make sense of it or to use RTVF systematically in the lesson. Post-hoc feedback which included simultaneous auditory and visual feedback might have promoted more attentive listening to student performances during piano lessons. The statements below serve to illustrate these views:

> *Oh, it was used to listen more carefully […] As I said, you know, you can pay more attention, you are more focused on listening, and not on playing and listening at the same time. (the student, interview after lesson 2)*
>
> *So if listening … listening to a 'playback' clarifies that sort of thing a lot, just the fact of hearing the 'playback', you know? (the teacher, interview after lesson 2)*

The use of post-hoc visual feedback was reported by participants during interviews. In case study A, both teacher and student reported making sense of the additional visual feedback in terms of MIDI parameters available to them, not only by identifying the music score as a graphic visualization but also by making sense of what happened in terms of performance.

> *The issue of MIDI was also very interesting, because it is pretty straightforward, it is very objective, you can clearly see, you know. The coolest thing is that it is very clear, you know, it is there, you know. You see what you did, what you didn't do, there's no way to deny it, right? It is recorded there, graphically, if you play the note it will appear, and if you don't play it, it will not appear, right. If you played strong it is shown with one colour, if you played it weak, it is shown with another colour. So it's well … I think it helps you a lot to see […] I think the visual shows it faster to you. (the student, interview after lesson 1)*
>
> *But the 'playback', with those visual graphics, explains a lot, right? (the teacher, interview after lesson 1)*

Post-hoc visual feedback on silent mode, i.e. without auditory feedback, was available to participants in the form of piano roll visualisation. This type of pedagogical use of technology-mediated feedback also occurred when the computer screen was scrolled from left to right, top to bottom, or vice-versa, by the first author, and when the student-teacher dyad used the frozen computer screen with a clear purpose.

The student-teacher dyad used silent visual feedback systematically, particularly in lesson 2, since they related aspects of the piano performance, such as dynamics and dynamic balance, to aspects of technology in terms of MIDI parameters and the piano roll visualisation, for example MIDI note colours and key velocity numbers displayed on the computer screen.

Visual feedback for dynamics: the role of MIDI note colours. This section discusses the findings from the MIDI-based qualitative data analyses (MIDI QDA), particularly on the pedagogical use of post-hoc visual feedback for dynamics regarding MIDI note colour differences. A considerable amount of MIDI data were collected and recorded on DAW software and used qualitatively through piano roll visualisations.

The focused application of post-hoc visual feedback in silent mode occurred in lesson 2 when the student-teacher dyad worked on dynamics and dynamic balance, between right and left hands. In lesson 2, the teacher reported that she wanted the student 'to get a little more expression in his left hand [even if he has to] to stay at a lower level [compared with the right hand] for the opening musical bars (Fig. 2) so that the left hand could accompany the dynamics contour provided by the right hand.

Fig. 2: Mozart *Piano Sonata No. 16* in C major, K. 545, fragment, second movement, bars 1-12 (Leipzig: Peters, 1938) (HAMOND, 2017: 257). Key: Taken from IMSLP website (http://imslp.org/).

Two recordings of MIDI data corresponding to the excerpts of piano performances were made. In the first recording, the student played alone with both hands. In the second recording, the teacher played the right hand while the student played the left hand. The resulting recorded data were assessed initially by using post-hoc visual feedback in normal mode, and then by using post-hoc feedback in silent mode. These showed two main differences in terms of different MIDI note colours and different key velocity numbers.

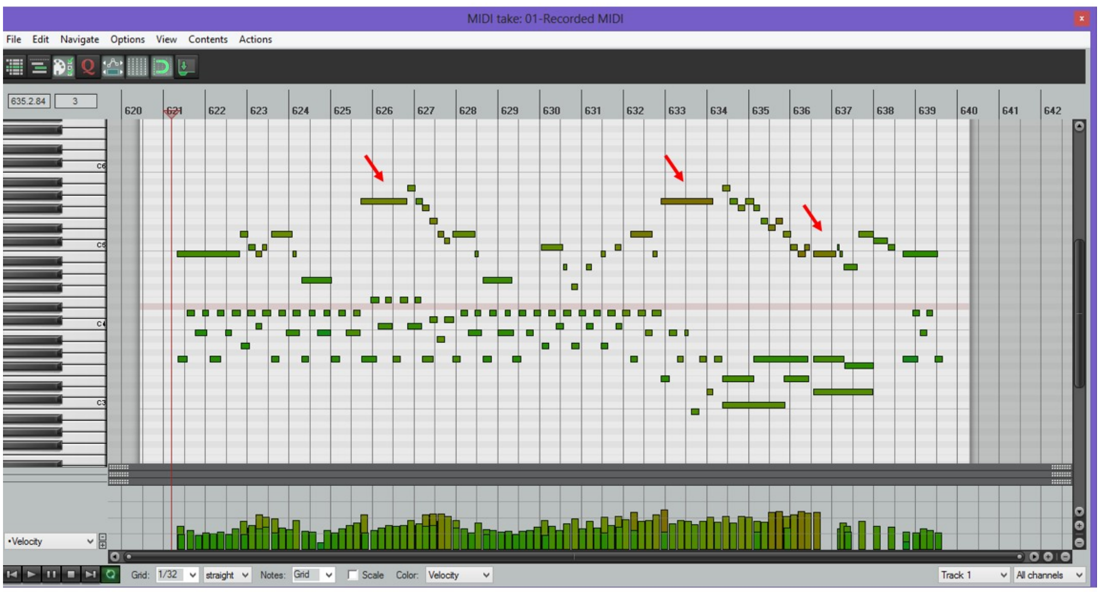

Fig. 3. DAW software screenshot focusing on dynamic balance, lesson 2 when the student is playing alone (HAMOND, 2017: 258).

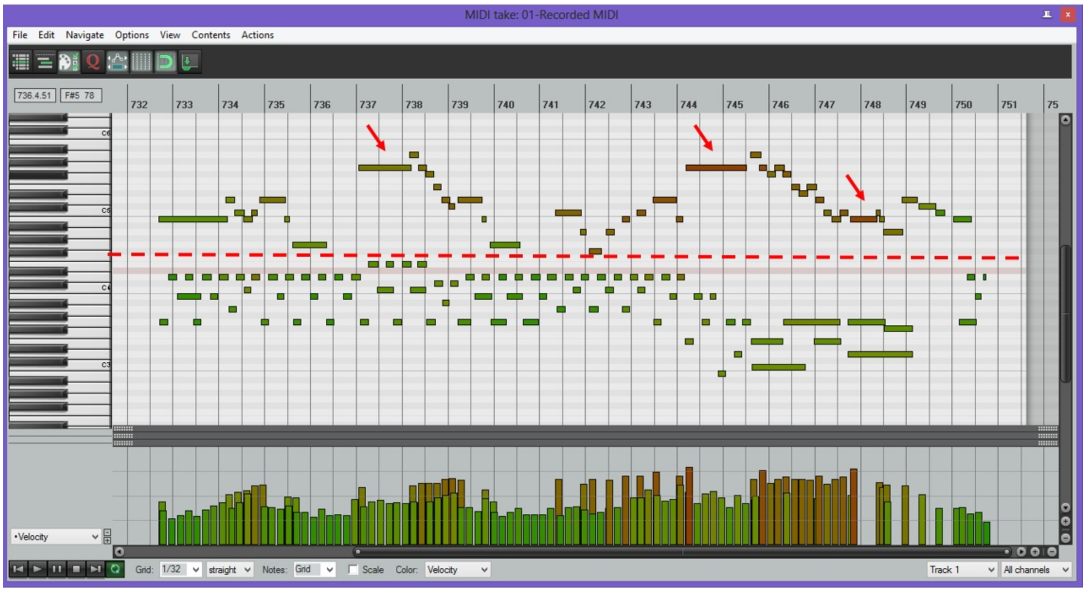

Fig. 4: DAW software screenshot focusing on dynamic balance, lesson 2 when the teacher plays alongside the student (HAMOND, 2017: 258).

The same colour nuances were noticed when the student played a chosen excerpt alone (Fig. 3). Shading differences in the MIDI notes denote differences in dynamics across notes. The arrows indicate the slight dynamic contour on the right-hand performance of the student (Fig. 3). However, greater colour differences were observed when the student (left hand) accompanied the teacher (right hand) (Fig. 4). Shading differences of the MIDI notes denote differences in dynamics across notes. Symbols above the red dotted line indicate the teacher's right hand; those below, the student's left hand. The arrows indicate the dynamic contour on the right-hand performance of the teacher. Visual feedback through the colour differences in MIDI notes show that a greater dynamic balance between right and left hands can be expected from the student when playing alone.

Visual feedback for dynamics: the role of key velocity numbers. This section discusses the pedagogical use of post-hoc visual feedback for dynamics regarding another type of information that was available: key velocity numbers. Differences between the two piano roll visualisations of recorded performances were also explored by the teacher-student dyad in lesson 2. There was evidence of how dynamics and dynamic contour changed when the student played alone and with the teacher (Fig. 5). The line contours in Fig. 5 show the key velocity number per each played note in sequential order for the opening musical bars, i.e. bars 1 to 8.

The key velocity numbers were plotted for the two performances: the student's left hand when playing alone and when accompanying the teacher's right hand. The bottom contour line (thin line) was obtained when the student played both hands. The upper contour line (thick line) was obtained when the student was accompanying the teacher whilst playing the Alberti bass. The research outcome indicates that the student was responding to the dynamic contour proposed by the teacher. This could be accessed afterwards and could enhance the student's conscious awareness of his own performance outcome. The change in key velocity numbers indicated a change in the dynamics for the student left hand when playing alongside the teacher's right hand.

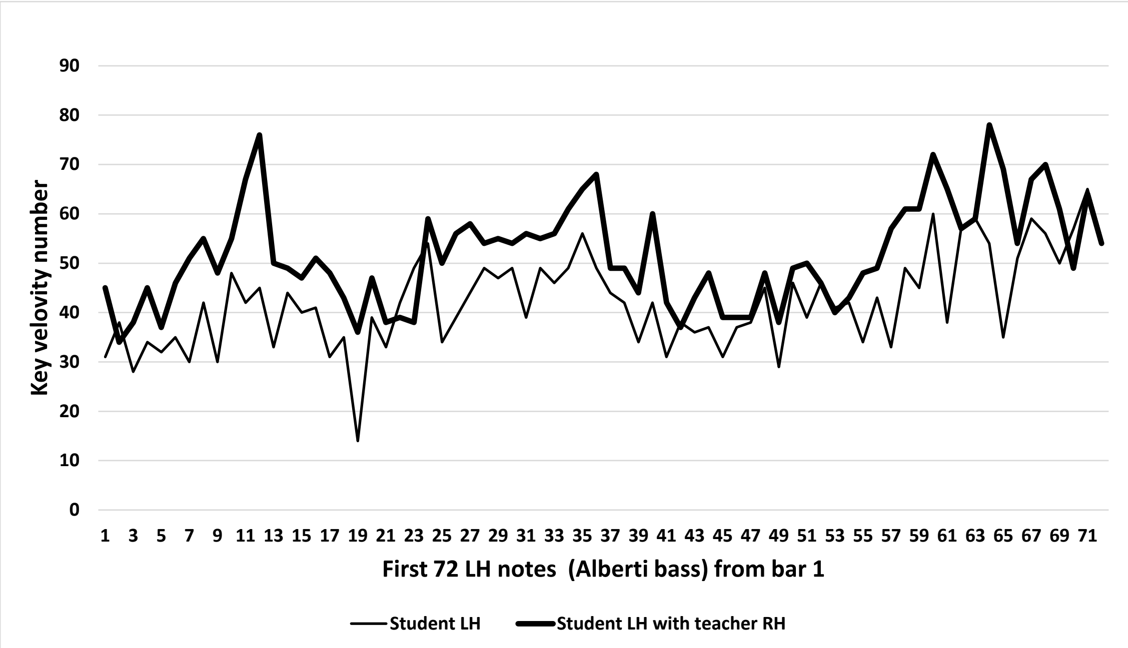

Fig. 5: Differences in dynamic contour through key velocity numbers corresponding to the student's left hand activity: (a) the bottom line shows the dynamic contour when the student played alone; (b) the top line shows the dynamic contour for the same notes when the student accompanied the teacher (HAMOND, 2017).

This suggests that, through the application of post-hoc visual feedback in silent mode represented both in MIDI note colours and key velocity numbers, the student was able to become more consciously aware of his own performance and was able to change the way he was playing. The dynamic contour of the left hand was shown to have increased when accompanying the right-hand performance of the teacher.

Perspectives on the use of post-hoc visual feedback for dynamics. Participants reported their perspectives on the use of post-hoc visual feedback during the semi-structured interviews. The student and teacher stated that they could make sense of the visual feedback – in terms of MIDI note colours and key velocity numbers – in supporting them to understand what happened in terms of dynamics. Differences in perception of MIDI parameters for either MIDI note colours or key velocity numbers were very clear when comparing the teacher and student interview data. The teacher readily perceived dynamic contour by interpreting variations of MIDI notes in colour. On the contrary, the student rapidly perceived dynamic contour by checking differences between key velocity numbers of the same MIDI notes which had been discussed in the lesson as reported below in interviews after lesson 2.

> *Yeah, and then today it was helpful [the application] of … of colours and numbers in this part, it was also useful for … […] We take a little bit of time to [realize] the numbers […]. The colour is visualized much faster. You look there, it became red [saying ta-ta-ta]. The number… you take longer to read each number, our brain takes longer to … well… I think they are two different things, you know. (the teacher, interview after lesson 2)*

> *Well… I think it was very interesting, because sometimes you cannot differentiate one colour from another very well, and the number is quite accurate, you know if it was one-tenth more than the other, you can see the number. (the student, interview after lesson 2)*

Post-hoc visual feedback seemed to allow participants to associate specific musical performance parameters with MIDI parameters in the piano studio. This was evident through the student's self-report after lesson 2:

> *[…] you can see the issue of dynamics, you can see the direction of the phrasing, if it is* crescendo *or* decrescendo*, to see the accents … You can see everything there in the graph. (the student, interview after lesson 2)*

Despite any differences in the type of data preference, both the student and teacher agreed on the potential benefits of using post-hoc visual feedback in enhancing piano learning and performance and, in this case, of dynamics and dynamic balance between right and left hands of a chosen piece over two piano lessons.

Discussion

This paper has focused on the research outcomes of one case study from a more extensive project (HAMOND, 2017) which investigated pedagogical uses of technology-mediated feedback in HE piano studios. It reported the pedagogical use of additional visual feedback for enhancing dynamics in an HE piano studio when a student-teacher dyad was working on improving the playing of a movement of a classical sonata.

Multi-methods qualitative data analyses involved video, MIDI and interview QDA. The video QDA approach focused on the patterns of additional visual and auditory feedback in either real-time or post-hoc. The student-teacher dyad worked on dynamics when using post-hoc visual feedback in two forms: normal mode and silent mode. Although RTVF was available to participants whilst they played the chosen piece and MIDI data were being recorded, they did not use RTVF for the learning enhancement of dynamics. This might be related to the fact that the piano roll visualization in real-time does not discriminate MIDI note colour, nor key velocity number regarding intensity/loudness/dynamics since all MIDI notes were shown in black. MIDI QDA provided the analysis of both piano roll visualisation corresponding to their performances. MIDI QDA revealed the use of additional visual feedback in piano lessons for an example case study in an HE piano studio.

Interview QDA findings supported those of the video and MIDI QDA. The student-teacher dyad reported that the piano roll visualisation available on the computer screen could be taken as an alternative visual representation of piano performances. When post-hoc visual feedback is applied in piano studios, nuances in the piano roll visualisation of performances were inferred to be closer to the nuances in the actual student performance. Additional visual feedback might also reduce the gap in conventional piano studios when reporting on the plasticity of a piano performance and the corresponding music notation which is immutable (BAUTISTA; ECHEVERRÍA; POZO; BRIZUELA, 2009. HULTBERG, 2002).

Research outcomes of this study build on an existing body of research. Firstly, the study complements technology-based instrumental and singing learning research in HE (BENSON, 1998. BRANDMEYER, 2006. DANIEL, 2001. RILEY, 2005. SADAKATA *et al*., 2008. TOMITA; BARBER, 2008. ZHUKOV, 2010). It also complements previous RTVF instrumental and singing learning research (BRANDMEYER, 2006. SADAKATA *et al*., 2008. WELCH, 1983, 1985b. WELCH *et al*., 2005) by investigating the use of post-hoc visual feedback in an HE piano studio. Finally, findings of this study agree with those of previous experimental studies which analysed piano performance recordings by associating performance parameters (e.g. dynamics) and MIDI parameters (e.g. MIDI notes colours or key velocity numbers) (BERNAYS; TRAUBE, 2014. BRESIN; BATTEL, 2000. PALMER, 1989, 1996. REPP, 1996). The application of additional visual feedback in an HE piano studio can optimise traditional pedagogical approaches in one-to-one piano learning and teaching; this also aligns with previous studies (cf. CREECH; GAUNT, 2012 for an overview). Visual feedback can enhance the student's conscious-awareness of their own performance outcomes; thus, an enhancement of learning leads to a tangible change and improvement in the student's performance.

Conclusion

The field of technology-based learning in an HE piano studio suggests that additional visual feedback holds potential for enhancing piano learning and performance, specifically for improving particular musical performance parameters such as dynamics, as demonstrated in this paper. Additional visual feedback, whether combined with auditory feedback or not, has been successfully applied as an educational tool in augmenting conscious-awareness of the student and the teacher on their own piano performances. Recent research has shown the benefits of using RTVF in singing studios (WELCH *et al*., 2005) and in percussion studios (BRANDMEYER, 2006. SADAKATA *et al*., 2008). However, the research on which this paper is based highlights the advantage of using post-hoc visual feedback in piano studios. Further research is recommended to understand better the application of visual feedback generated by a technology system in other learning stages (e.g. beginner, intermediate, advanced) and for other repertoire music styles (e.g. baroque, classical, romantic, or contemporary) and for developing other-than-piano performance skills, such as piano improvisation. Visual feedback can also be investigated as a self-study pedagogical tool at home and as a distance learning tool, complementing previous studies (PIKE; SHOEMAKER, 2013. HENLEY; LAU; SPRY, 2016). Research outcomes of this study also relate to group piano teaching since the instrument used is a digital piano, thus aligning with previous perspectives (FISHER, 2010. PIKE, 2017. STEPHENS-HIMONIDES; HILLEY, 2016). Overall, there is evidence that technology can enhance learning in the music studio, including for advanced learners.

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References

ACITORES, Alicia Peñalba. Towards a Theory of Proprioception as a Bodily Basis for Consciousness in Music. *In:* CLARKE, David; CLARKE, Eric. (eds.), *Music and Consciousness: Philosophical, Psychological, and Cultural Perspectives*. Oxford: Oxford University Press, 2011. p. 215-231. http://dx.doi.org/10.1177/0305735695231001.

BANTON, Louise J. The Role of Visual and Auditory Feedback During the Sight-Reading of Music. *Psychology of Music,* v. 23, p. 3-16, 1995.

BAUTISTA, Alfredo; ECHEVERRÍA, Ma del Puy Pérez; POZO, J. Ignacio; BRIZUELA, Bárbara M. Piano Students' Conceptions of Musical Scores as External Representations: A Cross-Sectional Study. *Journal of Research in Music Education,* v. 57, n. 3, p. 181-202, 2009. http://dx.doi.org/10.1177/0022429409343072.

BENSON, Cynthia. *The Effects of Instructional Media on Group Piano Student Performance Achievement and Attitude*. (D.M.A.), University of Texas, Austin, 1998.

BENSON, Cynthia; FUNG, C. Victor. Comparisons of Teacher and Student Behaviors in Private Piano Lessons in China and the United States. *International Journal of Music Education,* v. 23, n.1, p. 63-72, 2005. http://dx.doi.org/10.1177/0255761405050931.

BERA. *Ethical Guidelines for Educational Research 2011*. Retrieved from: https://www.bera.ac.uk/researchers-resources/publications/ethical-guidelines-for-educational-research-2011. Accessed on: 23 Aug. 2016.

BERNAYS, Michel; TRAUBE, Caroline. Investigating Pianists' Individuality in the Performance of Five Timbral Nuances Through Patterns of Articulation, Touch, Dynamics, and Pedaling. *Frontiers in Psychology*, v. 5, n. 157, p. 1-19, 2014. http://dx.doi.org/10.3389/fpsyg.2014.00157.

BISHOP, Laura; GOEBL, Werner. When They Listen and When They Watch: Pianists' Use of Nonverbal Audio and Visual Cues During Duet Performance. *Musicae Scientiae*, v. 19, n. 1, p. 84–110, 2015. http://dx.doi.org/10.1177/1029864915570355.

BISHOP, Laura; GOEBL, Werner. Communication for Coordination: Gesture Kinematics and Conventionality Affect Synchronization Success in Piano Duos. *Psychological Research*, v. 82, n. 6, p. 1177–94, 2018.

BRAA, Kristin; VIDGEN, Richard. Interpretation, Intervention, and Reduction in the Organizational Laboratory: A Framework for In-Context Information System Research. *Accounting, Management and Information Technologies*, v. 9, n. 1, p. 25-47, 1999.

BRANDMEYER, Alex. *Real-Time Visual Feedback in Music Pedagogy: Do different visual representations have different effects on learning?* Thesis (Master's) - Radboud University Nijmegen, 2006.

BRAUN, Virginia; CLARKE, Victoria. Using Thematic Analysis in Psychology. *Qualitative Research in Psychology,* v. 3, n. 2, p. 77-101, 2008. http://dx.doi.org/10.1191/1478088706qp063oa.

BRESIN, Roberto; BATTEL, Giovanni Umberto. Articulation Strategies in Expressive Piano Performance Analysis of Legato, Staccato, and Repeated Notes in Performances of the Andante Movement of Mozart's Sonata in G Major (K 545). *Journal of New Music Research*, v. 29, n. 3, p. 211-224, 2000. http://dx.doi.org/10.1076/jnmr.29.3.211.3092.

BROWN, Rachel M.; PALMER, Caroline. Auditory-Motor Learning Influences Auditory Memory for Music. *Memory & Cognition*, v. 40, n. 4, p. 567-578, 2012. http://dx.doi.org/10.3758/s13421-011-0177-x.

BRYAN, Daphne Margaret. *Student Teacher Interaction in One-To-One Piano Lesson.* Dissertation (PhD) - University of Sheffield, Sheffield, 2004.

BURWELL, Kim. *Instrumental Teaching and Learning in Higher Education.* Dissertation (PhD) - University of Kent, 2010.

CAREY, Gemma; GRANT, Catherine. Peer Assisted Reflection in Studio Music Teaching. *In:* KLOPPER, Christopher; DREW, Steve. (eds.), *Teaching for Learning and Learning for Teaching: Cases Incontext of Peer Review of Teaching in Higher Education*. Rotterdam, Netherlands: Sense, 2015. p. 63-78. http://dx.doi.org/10.1007/978-94-6300-289-9.

CHAFFIN, Roger; IMREH, Gabriela. Practicing Perfection: Piano Performance as Expert Memory. *Psychological Science*, v. 13, n. 4, p. 342-349, 2002. http://dx.doi.org/10.1111/j.0956-7976.2002.00462.x.

CREECH, Andrea; GAUNT, Helena. The Changing Face of Individual Instrumental Tuition: Value, Purpose and Potential. *In:* MCPHERSON, Gary; WELCH, Graham. (eds.). *The Oxford Handbook of Music Education* (Vol.1). Oxford: Oxford University Press, 2012. p. 694-711.

DAMASIO, Antonio. *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*. London: Heinemann, 2002.

DANIEL, Ryan. Self-Assessment in Performance. *British Journal of Music Education*, v. 18, n. 3, p. 215-226, 2001.

DEMOS, Alexander P.; CHAFFIN, Roger. *A Software Tool for Studying Music Practice: SYMP (Study Your Music Practice).* Poster presented at the European Society for the Cognitive Sciences of Music (ESCOM), Jyväskylä, Finland, 2009. Retrieved from: http://musiclab.uconn.edu/wp-content/uploads/sites/290/2013/10/DemosESCOM-Poster.pdf. Accessed on: 23 Aug. 2016.

FINNEY, Steven A. Auditory Feedback and Musical Keyboard Performance. *Music Perception,* v. 15, n. 2, p. 153-174, 1997.

FINNEY, Steven A.; PALMER, Caroline. Auditory Feedback and Memory for Music Performance: Sound Evidence for an Encoding Effect. *Memory & Cognition,* v. 31, n. 1, p. 51-64, 2003.

FISHER, Christopher. *Teaching Piano in Groups*. New York: Oxford University Press, 2010.

FLICK, Uwe. An Introduction to Qualitative Research. London: Sage, 2009.

FRANÇOIS, Alexandre R. J.; CHEW, Elaine; THURMOND, Dennis. *Visual Feedback in Performer-Machine Interaction for Musical Improvisation*. *In:* NEW INTERFACES FOR MUSICAL EXPRESSION (NIME07)*,* 7, 2007, New York, NY, USA. *Proceedings* [...]. New York, NY, 2007. p. 277-280. Retrieved from: http://www.nime.org/proceedings/2007/nime2007_277.pdf. Accessed on: 23 Aug. 2016.

GOEBL, Werner; PALMER, Caroline. Synchronization of Timing and Motion Among Performing Musicians. *Music Perception*, v. 26, n. 5, p. 427-438, 2009.

GUBA, Egon G. Criteria for Assessing the Trustworthiness of Naturalistic Inquiries. *Educational Communication and Technology,* v. 29, n. 2, p. 75-91, 1981.

HALLAM, Susan. *Instrumental Teaching: A Practical Guide to Better Teaching and Learning.* Oxford: Heinemann, 1998.

HALLAM, Susan. The Development of Metacognition in Musicians: Implications for Education. *British Journal of Music Education*, v. 18, n. 1, p. 27-39, 2001. http://dx.doi.org/10.1017/S0265051701000122.

HALWANI, Gus F.; LOUI, Psyche; RÜBER, Theodor; SCHLAUG, Gottfried. Effects of Practice and Experience on the Arcuate Fasciculus: Comparing Singers, Instrumentalists, and Non-Musicians. *Frontiers in Psychology,* v. 2, n. 156, p. 1-9, 2011. http://dx.doi.org/10.3389/fpsyg.2011.00156.

HAMOND, Luciana. Feedback on Elements of Piano Performance: Two Case Studies in Higher Education Studio. *In:* WILLIAMON, Aaron; GOEBL, Werner. (eds). *Proceedings of International Symposium of the Performance Science (ISPS 2013)*, University of Music and Performing Arts, Vienna, Austria/Brussels, Belgium: European Association of Conservatoires (AEC), 2013a. p. 33-38.

HAMOND, Luciana. Verbal and Non-Verbal Feedback in Higher Education Level Piano Settings: Two Case Studies. Paper presented at Research in Music Education (RIME), Exeter, UK, 2013b, p. 39-40.

HAMOND, Luciana F. *The Pedagogical Use of Technology-Mediated Feedback in a Higher Education Piano Studio: An Exploratory Action Case Study*. Unpublished PhD thesis, UCL-Institute of Education, University College London, London, UK, 2017.

HATTIE, John; TIMPERLEY, Helen. The Power of Feedback. *Review of Educational Research,* v. 77, n. 1, p. 81-112, 2007. http://dx.doi.org/10.3102/003465430298487.

HENLEY, Jennie; LAU, Fiona; SPRY, Hannah. When Technology and Pedagogy Meet: Developing Expertise in Piano Lessons via Google Chat. *In:* HIMONIDES, Evangelos; KING, Andrew. (eds). *Proceedings of the Sempre MET2016: Researching Music, Education, Technology*. London: International Music Education Research Centre, iMerc, 2016. p. 109-144.

HIMONIDES, Evangelos. The Misunderstanding of Music-Technology-Education: A Meta Perspective. *In:* MCPHERSON, Gary; WELCH, Graham. (eds.). *The Oxford Handbook of Music Education Volume 2*. New York: Oxford University Press, 2012. p. 433-456.

HOUNSELL, Dai. Student Feedback, Learning and Development. *In:* SLOWEY, Maria; WATSON, David. (eds.). *Higher Education and the Lifecourse*. Maidenhead: SRHE & Open University Press, 2003. p. 67-78.

HULTBERG, Cecilia. Approaches to Music Notation: The Printed Score as a Mediator of Meaning in Western Tonal Tradition. *Music Education Research*, v. 4, n. 2, p. 185-197, 2002. http://dx.doi.org/10.1080/1461380022000011902.

JØRGENSEN, Harald. Student Learning in Higher Instrumental Education: Who Is Responsible? *British Journal of Music Education*, v. 17, n. 1, p. 67-77, 2000.

KEMMIS, Stephen. Action Research. *In:* HAMMERSLEY, Martin (ed.). *Educational Research: Current Issues* (Vol. 1). London: Paul Chapman in association with the Open University, 1993. p. 177-190.

KING, Andrew. Collaborative Learning in the Music Studio. *Music Education Research*, v. 10, n. 3, p. 423-438, 2008. http://dx.doi.org/10.1080/14613800802280167.

KOSTKA, Marilyn J. An Investigation of Reinforcements, Time Use, and Student Attentiveness in Piano Lessons. *Journal of Research in Music Education*, v. 32, n. 2, p. 113-122, 1984.

MAGILL, Richard A. *Motor Learning: Concepts and Applications*. (3rd ed.). Dubuque, IA: Wm. C. Brown, 1989.

MCPHERSON, Andrew. Portable Measurement and Mapping of Continuous Piano Gesture. *In:* NEW INTERFACES FOR MUSICAL EXPRESSION *(NIME 2013),* 2013, Seoul, Korea, 2013. p.152-157. Retrieved from: http://nime.org/proceedings/2013/nime2013_240.pdf. Accessed on: 23 Aug. 2016.

MIKLASZEWSKI, Kacper. A Case Study of a Pianist Preparing a Musical Performance. *Psychology of Music*, v. 17, n. 2, p. 95-109, 1989. http://dx.doi.org/10.1177/0305735689172001.

MOORE, Emma; SCHAEFER, Rebecca; BASTIN, Mark; ROBERTS, Neil; OVERY, Katie. Musically Cued Motor Training and White Matter Connectivity. *In:* HIMONIDES, Evangelos; KING, Andrew. (eds). *Proceedings of the Sempre MET2016: Researching Music, Education, Technology*. London: International Music Education Research Centre, iMerc, 2016, p. 25-30.

NIELSEN, Siw. Self-Regulating Learning Strategies in Instrumental Music Practice. *Music Education Research*, v. 3, n. 2, p. 155-167, 2001. http://dx.doi.org/10.1080/14613800120089223.

PALMER, Caroline. Computer Graphics in Music Performance Research. *Behavior Research Methods*, v. 21, n. 2, p. 265-270, 1989.

PIKE, Pamela. *Dynamic Group-Piano Teaching: Transforming Group Theory into Teaching Practice*. New York, NY: Routledge, 2017.

PIKE, Pamela; SHOEMAKER, Kristin. The Effect of Distance Learning on Acquisition of Piano Sight-Reading Skills. *Journal of Music, Technology and Education*, v. 6., n. 2, p. 147-162, 2013. http://dx.doi.org/10.1386/jmte.6.2.147_1.

REPP, Bruno H. The Dynamics of Expressive Piano Performance: Schumann's "Träumerei" Revisited. *The Journal of the Acoustical Society of America*, v. 100, n. 1, p. 641-650, 1996.

RILEY, Kathleen. Understanding Piano Playing through MIDI: Students' Perspectives on Performance Analysis and Learning. *American Music Teacher*, v. 54, n. 6, p. 33-37, 2005.

SADAKATA, Makiko; HOPPE, David; BRANDMEYER, Alex; TIMMERS, Renee; DESAIN, Peter. Real-Time Visual Feedback for Learning to Perform Short Rhythms with Expressive Variations in Timing and Loudness. *Journal of New Music Research*, v. 37, n. 3, p. 207-220, 2008. http://dx.doi.org/10.1080/09298210802322401.

SAVAGE, Jonathan. Reconstructing Music Education Through ICT. *Research in Education*, v. 78, n. 1, p. 65-77, 2007.

SCHMIDT, Richard A.; LEE, Tim D. *Motor Control and Learning: A Behavioral Emphasis* (5th ed.). Champaign, IL: Human Kinetics, 2011.

SHENTON, Andrew K. Strategies for Ensuring Trustworthiness in Qualitative Research Projects. *Education for Information,* v. 22, n. 2, p. 63-75, 2004.

SIEBENALER, Dennis J. Analysis of Teacher-Student Interactions in the Piano Lessons of Adults and Children. *Journal of Research in Music Education*, v. 45, n. 1, p. 6-20, 1997.

SPEER, Donald R. An Analysis of Sequential Patterns of Instruction in Piano Lessons. *Journal of Research in Music Education*, v. 42, n. 1, p. 14-26, 1994.

STAKE, Robert E. *The Art of Case Study Research.* London: Sage, 1995.

STEPHENS-HIMONIDES, Cynthia; HILLEY, Martha. *Technology and Group Teaching*. *In:* KING, Andrew; HIMONIDES, Evangelos; RUTHMANN, S. Alex. (eds.). The Routledge Companion to Music, Technology, and Education Routledge, 2016. p. 319-330. Retrieved from: https://www.routledgehandbooks.com/doi/10.4324/9781315686431.ch28. Accessed on: 23 Apr 2018.

THOMPSON, William F.; DIAMOND, C. T. Patrick; BALKWILL, Laura-Lee.The Adjudication of Six Performances of a Chopin Etude: A Study of Expert Knowledge. *Psychology of Music*, v. 26, n. 2, p. 154-174, 1998.

THOMPSON, Sam; WILLIAMON, Aaron. Evaluating Evaluation: Musical Performance Assessment as a Research Tool. *Music Perception*, v. 21, n. 1, p. 21-41, 2003.

TOMITA, Yo; BARBER, Graham. New Technology and Piano Study in Higher Education: Getting the Most out of Computer-Controlled Player Pianos. *British Journal of Music Education*, v. 13, n. 2, p. 135-141, 2008. http://dx.doi.org/10.1017/S0265051700003107.

WELCH, Graham F. *Improvability of Poor Pitch Singing: Experiments in Feedback.* Dissertation (PhD) - Institute of Education, University of London, London, 1983.

WELCH, Graham F. A Schema Theory of How Children Learn to Sing in Tune. *Psychology of Music*, v. 13, n. 1, p. 3-18, 1985a.

WELCH, Graham F. Variability of Practice and Knowledge of Results as Factors in Learning to Sing in Tune. *Bulletin of the Council for Research in Music Education*, n. 85, p. 238-247, 1985b.

WELCH, Graham F.; HOWARD, David M.; HIMONIDES, Evangelos; BRERETON, Jude. Real-Time Feedback in the Singing Studio: An Innovatory Action-Research Project Using New Voice Technology. *Music Education Research*, v. 7, n. 2, p. 225-249, 2005. http://dx.doi.org/10.1080/14613800500169779.

WIENER, Norbert. *Cybernetics: Or Control and Communication in the Animal and the Machine.* Cambridge, MA: The MIT Press, 1961.

WÖLLNER, Clemens; WILLIAMON, Aaron. An Exploratory Study of the Role of Performance Feedback and Musical Imagery in Piano Playing. *Research Studies in Music Education,* v. 29, n. 1, p. 39-54, 2007. http://dx.doi.org/10.1177/1321103X07087567.

YIN, Robert K. *Case Study Research: Design and Methods.* (5th ed.). London: Sage, 2014.

ZHUKOV, Katie. Piano Assessment in Australian Higher Education – Time for a Change? *In:* HANNAN, Michael (ed.). The Musician in Creative and Educational Spaces of the 21st Century. *Proceedings of the 18th International Seminar of the Commission for the Education of the Professional Musician (CEPROM),* Shanghai, China, 2010. p. 92-96. Retrieved from: https://issuu.com/official_isme/docs/2010_ceprom_proceedings. Accessed on: 21 Dec. 2015.

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