Interactive technologies in the instrumental music classroom:

a case study with the Music Paint Machine.

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Abstract

In this paper we describe a nine-month longitudinal study in which twelve children (1st and 2nd grade) learned to play the clarinet. Six of the children received instruction with an interactive music system, called the Music Paint Machine. This educational technology allows a musician to make a digital painting by playing music and by making various movements on a coloured pressure mat. The aim of the system is to support instrumental music teaching and learning by stimulating musical creativity, by promoting an embodied understanding of music and by supporting the development of an optimal musician-instrument relationship.

The overall goal of the longitudinal study was (1) to integrate the Music Paint Machine in instrumental music instruction in order to develop good practices with the system and (2) to investigate the possible effect of instruction with the system on the learning process.

The study adopted a non-equivalent control groups design with several pre-tests and a post-test. To measure the effectiveness of instruction with the system, children were administered the Primary and Intermediate Measures of Music Audiation (Gordon, 1986) as pre- and post-test. Furthermore, pre-tests were organised to map possible confounding variables, such as personality, home musical environment, motor skills and self-regulation skills. No statistically significant differences were found between the control and intervention group.

Dealing with the complexity of a real-life educational setting and with the requirements of the quasi-experimental design, this study has provided insights on methodology (design, measures, analysis) in music educational technology research. As such, it can contribute to the further development of this branch of educational research.
1. Introduction

The emergence of new technologies has always led to new possibilities for teaching and learning. In particular, the increasing computational power and the embedded computing continuously change the way we interact with computers and learn (Dourish, 2004). The traditional desktop computing is increasingly complemented and possibly even gradually replaced by a new breed of computational systems (iPads, smartphones) in which mouse and keyboard are exchanged for other types of sensors and controllers. Evidently, this offers possibilities for the design of new educational technologies and applications.

In the domain of music education, an emerging trend is the development of interactive systems that offer active ways of engaging with music, using the multimodal nature of the musical experience as a basis for visual, sonic and bodily interactions. Some of these systems focus at instrumental teaching and learning. They monitor a musician’s playing and provide auditory and visual feedback on music and movement (e.g. Larkin, Koerselman, Ong, & Ng, 2008; Ng, Larkin, Koerselman & Ong, 2007; Brandmeyer, Hoppe, Sadakata, Timmers & Desain, 2006; Howard, Welch, Brereton, Himonides, De Costa, Williams & Howard, 2004; Welch, Himonides, Howard, & Brereton, 2004).

Interactive music systems are assumed to stimulate the musical learning process (e.g. Pritchard and Woollard, 2010) for several reasons, such as: the engagement of multimodal processing capabilities (e.g. de Jong, 2010; Sweller, Van Meriënboer & Paas, 1998), the use of
objective performance measurement (e.g. Hoppe, Brandmeyer, Sadakata, Timmers, & Desain, 2006; Howard, et al., 2007), the stimulation of student autonomy and self-regulation (Carneiro, Lefrere & Steffens, 2011), the creation of a powerful learning environment (e.g. Jonassen, Campbell & Davidson, 1994), and their appeal to the daily life world of young people (e.g. Burnard, 2007; Folkestad, 2006). As such, interactive music systems have the potential contribute to a constructivist approach to instrumental teaching and learning. This approach is embodied and extended in the sense that new interactive technologies intervene with the multimodal aspects of perception and action that underlay how to play a music instrument.

Clearly, the belief in a didactic potential of interactive music systems needs to be substantiated on the basis of empirical studies. At this point we believe a critical stance is needed in relation to feedback, use of technologies, pedagogical model, and intervention studies. Due to the stimulation of multiple senses, feedback systems may cause a degrading of learning due to cognitive load (e.g. Sadakata, Hoppe, Brandmeyer, Timmers, & Desain, 2008; Thorpe, 2002), dependency (e.g. Ronsse, Puttemans, Coxon, Goble, Wagemans & Wenderoth, 2011; Schmidt, 2008) and the stimulation of an internal focus (e.g. Wulf & Lewthwaite, 2009). Innovative educational technologies may be used for the sake of the technologies and at the cost of the pedagogical goals. The pedagogical model may stick with the schoolish master-
apprentice model of traditional instrumental music teaching (Bowman, 2002; Hennessy, 2001; Lehmann, Sloboda, & Woody, 2007). Last but not least, there is a lack of longitudinal interventions studies that show the effectiveness in using interactive music systems for learning. Studies are often based one-shot experiences, a limited number of participants and a lack of statistical analysis that supports the findings. Therefore, studies are needed that take these issues into account and that pave the path towards full-blown intervention studies.

In this paper we address these issues on the basis of our work with the Music Paint Machine, an interactive music system that translates the combination of music and movement into a creative visualization, i.e. a digital painting. To avoid as much as possible the above-mentioned pitfalls, the design and implementation of the Music Paint Machine has been embedded in a framework that addresses pedagogy, technology and intervention (see Fig 1.1; see also Nijs, Moens, Lesaffre & Leman, 2012a).

Figure 1.1. Overview of the research framework. The research unfolded through the iteration between a pedagogical, a technological and empirical component.

Goals at these three levels guided the iterative process according to which the Music Paint Machine was designed and arrived at its current state. Although our study does not realize a full-blown intervention study, we believe that it contributes to that goal. In the following
sections we first shortly explain the system, then we report on our intervention study with the Music Paint Machine.

2. **The Music Paint Machine, a short introduction.**

The Music Paint Machine (henceforth: MPM) is an interactive music system that allows a musician to make a digital painting by playing music and by making various movements on a pressure sensing coloured mat. A detailed description is given elsewhere (Nijs et al, 2012a). Here we shortly describe the aims and features of the system.

2.1 **Educational goals of the Music Paint Machine**

Our overall objective is to enhance instrumental learning using the MPM as a facilitator for creativity, understanding, and control. Consequently, the MPM should invite learners to be playful with musical parameters (e.g. Deliège & Wiggins, 2006; Kratus, 1991) and enhance the occurrence of an optimal experience (e.g. Addessi & Pachet, 2005; Csikszentmihalyi, 1990; Woszczynski, Roth, & Segars, 2002). An experimental study with the MPM has shown its potential to induce this kind of experience (Nijs et al, 2012a, 2012b). In addition, we aim at supporting an embodied understanding of music (e.g. Leman, 2007; Bowman, 2004) by integrating body movement as an essential component of musical expression and by providing a multimodal experience in which body movement and music converge into a common visual stimulus, i.e. the digital painting. The MPM invokes a
variety of non-instrumental movements and as such stimulates bodily involvement. Based on the embodied music cognition paradigm (Leman, 2007; Bowman, 2004), it is believed that this appeals to the bodily basis of music learning. Finally, we aim at supporting the development of an optimal relationship between musician and musical instrument by using the combination of movement and music to control the multimodal interaction. The design concept of the system is based on a philosophical investigation of the musician-instrument relationship (Nijs, Lesaffre & Leman, in press). A key inspiration of the system is the notion of original motility and its importance for (musical) perception (Merleau-Ponty, 1945). These goals are reflected in the four basic features of the system.

2.2 Basic features of the Music Paint Machine

A first feature concerns the creative use of visual feedback. The system visualizes in real-time parameters of the music that is being played as well as how the musician moves while playing. For example, the system can provide information on the degree to which intonation is steady when dynamics changes (see figure 2.1).

Figure 2.1. The system shows changes in intonation when, as exemplified in this figure, the musician plays crescendo and diminuendo.

However, the visualization of music and movement is more than mere visual feedback on aspects of playing music. It invites users to
creatively use movement and music in order to obtain a personalized outcome, namely the digital “painting”. Consequently, the visualization can be considered a creative output that results from the expressive intentions of the musician (see Fig. 2.2).

Figure 2.2. An example of a creative output of playing with the system

Therefore our visual feedback differs from most existing interactive systems where visual feedback is most often in the form of symbolic representations (see Fig. 2.3 for some examples).

Figure 2.3. Some example of the kind of visual feedback that is used in interactive music systems. Upper left: Seeing Sound (Ferguson, 2006) - Upper right: Practice Space (Brandmeyer, Hoppe, Sadakata, et al., 2006) – Bottom left: WisingAd (Howard, et al., 2007) – Bottom right: AMIR (Larkin, Koerselman, Ong, & Ng, 2008)

Instead the MPM provides an enactive-iconic representation of the learner’s music and movement (Bruner, Oliver, & Greenfield, 1966).

A second feature concerns body movement as controller of the system. This feature invites the learner to actively use the body movements in order to generate a desired effect such as, for example, drawing from right to left instead of drawing from left to right by pointing left with the body. In this way, the system introduces a variability of movement, the deployment of which is believed to stimulate the development of body awareness and to increase
enactive — knowledge, i.e. knowing in and through the body (Juntunen & Westerlund, 2001). This approach to the body is related to the idea of differential learning (Schöllhorn, 2000) and to the variability of practice hypothesis (Schmidt, 1975). Using this approach, the system goes beyond the corporeal dimension of merely instrumental gestures (sound-producing and sound-facilitating; Jensenius, 2010).

A third feature concerns the adaptability to a variety of didactic practices. The software of the MPM allows the design of all kinds of practices to support different educational goals. For example, the mapping from musical and movement parameters to visual parameters can be changed. One educational goal might favour the mapping of pitch to vertical position (e.g. matching melodic patterns), while another educational goal might favour the mapping of pitch to colour transparency (e.g. when the goal concerns intonation). In addition, the range of the measured values (e.g. pitch, loudness) is adaptable to the learners’ range of notes (see Figure 2.4) or loudness (see Figure 2.5). At the same time, it allows challenging learners by setting ranges that delicately exceed their ranges.

**Figure 2.4.** The screen height of the Music Paint Machine’s visual output can be adapted to the player’s tessitura (range of notes).
Figure 2.5. Ranges of in- and output can be controlled to fine-tune the system to a player’s skills.

As such the system allows the teacher to create a learning context that appeals to but also challenges the current skill level of the learner.

A fourth feature concerns the control of conditions for optimal experience, using the features defined above. These conditions are: a balance between skills and challenge, clear goals every step of the way and unambiguous feedback (Csikszentmihalyi, 1990).

3. Learning to play the clarinet: An intervention study with the MPM.

In this section we describe a study with the MPM, in which 12 children learned to play the clarinet during nine months. The goal of the study was to develop good practices with the MPM in the classroom. In addition, we wanted to test the effectiveness of instruction with the system in supporting the musical learning process.

3.1 Methods

3.1.1. Participants

Twelve children (first and second grade, six boys and six girls) and one teacher (the researcher in this study and first author of this paper) participated. Seven children were grade one and five children were
grade two. Most of the children’s parents were highly educated. The researcher-teacher received formal training in music performance and music teaching. He was a clarinet, saxophone and ensemble teacher for fourteen years.

3.1.2. Design

This study was conducted during nine months. In order to investigate the possible effect of instruction with the MPM, a non-equivalent control groups design was used. Six children were non-randomly assigned to the intervention group and received instruction with the support of the system. A timetable was constructed to schedule the lessons of the children in such a way that the parents’ organizational demands were met but at the same time age and grade of the children were as equally as possible distributed (see Table 3.1).

Table 3.1. Assignment of the children to the control or treatment group aimed at an equal distribution with regard to age and gender.

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All children were pre-tested (O) and post-tested (O). In Table 3.2, a diagram of the experimental design is shown.
Table 3.2. Diagram of the experimental design of the study. Groups were non-randomized (NR). The study used four measurements (O) of music aptitude as dependent variable. In between the measurements, children received instrumental music instruction. The treatment group received instruction with the Music Paint Machine (X).

It was hypothesized that instruction with the MPM (independent variable) would enhance the development of tonal and rhythmic discrimination skills and, as such, to the developmental tonal and rhythmic aptitude (dependent variable) (Gordon, 1986).

3.1.3. Procedure

In this study, the researcher acted as teacher. The practical reason for this decision concerned the difficulty to find a teacher who wanted to work a whole year with the MPM. The substantive reason concerned the unique position the teacher-researcher holds in order to gather, interpret and use research-generated data about the different aspects of teaching and learning (Regelski, 1994; Campbell, 2011). Participants were recruited through a large-scale information campaign in local schools. An information letter and a website were provided with detailed information on the program, the experiment, the enrolment procedures, practical matters (e.g. location, important dates), the requirements (minimum attendance and participation in data collection) to enrol for the program and the compensations
participants would receive. There was no selection procedure. A meeting was organized during which the necessary information was provided so parents could make an informed decision on enrolling their child for the program. All parents who enrolled their child signed an informed consent.

Prior to the instruction, the parents and the children participated in a number of pre-tests. Parents were administered three questionnaires in which they reported on their child’s self-regulation skills (Schwarzer, Diehl, & Schmitz, 1999), home musical environment (in-house designed) and personality (Mervielde & De Fruyt, 1999). The children participated in two standardized tests. One test probed the children's music aptitude (Primary Measure of Music Audiation; Gordon, 1986); the other tested the children’s motor skills (M-ABC-2; Henderson, Sugden, & Barnett, 2007).

Lessons were given once a week for a period of 9 months, with the exception of school holiday weeks. Children attended class in groups of three and received instruction during one hour. The first two groups received regular instruction; the second two groups received instruction with the Music Paint Machine. The learning content for all groups was kept the same as much as possible. Lessons were based on an aural approach in which the children were guided from sound to sign on the basis of a carefully designed learning path. The children
learned to play by ear, starting from well-known children’s song. Both
improvisation and composition were an integral part of the lessons.
Throughout the nine months of instruction, several variables were
repeatedly measured. First, parents were asked to keep a log of their
child’s practice time per day and of the help they provided. Second,
at the end of each lesson, the children completed a questionnaire on
classroom experience. Third, every three months the children were
administered the music aptitude test (Gordon, 1986).

3.2 Results

3.2.1. Development of good practices

The weekly use of the Music Paint Machine has led to several good
practices with regard to the use of visual feedback and movement.
These practices can be categorized into free exploration, guided
exploration and direct instruction. Free exploration consisted of sessions
in which learners were completely free to make a digital painting.
Figure 3.1 shows some examples of digital paintings that resulted from
the free play sessions.

Figure 3.1. Four examples of flashcards that were used in musical games
to develop musical skills and to stimulate musical creativity. Some
flashcards used Morse code to learn about note duration and rhythm
(top left), to develop children’s emotional expression (top right), to use
movement (bottom left) or to be creative with melodic contour (bottom right).

Guided exploration was based on activities with game cards that contained specific tasks with regard to different musical, movement and visual parameters. In Figure 3.2, some examples of these game cards are presented.

Figure 3.2. Four examples of flashcards that were used in musical games to develop musical skills and to stimulate musical creativity. Some flashcards used Morse code to learn about note duration and rhythm (top left), to develop children’s emotional expression (top right), to use movement (bottom left) or to be creative with melodic contour. This exercise could be done with or without the Music Paint Machine.

Direct instruction activities consisted of consecutive sessions in which learning content was gradually built up based on carefully designed practices with the system. Figures 3.3, 3.4, 3.5 and 3.6 give some examples.

Figure 3.3. The “painting” of the MPM gives visual feedback on pitch differences (a). In this example pitch is mapped to position on the vertical axis, while duration is mapped to length on the horizontal axis. Children can try to overwrite (b) or copy (c) tonal or rhythmic patterns.
**Figure 3.4.** Painting duration & rhythm: an enactive basis for symbolic representation. First students learn about long and short, then the learn how to “measure” duration, then learn rhythmic patterns and, finally, they learn about notation.

3.2.2. Effectiveness of instruction with the system

The results of the PMMA pre-test show moderate scores in most groups. In table 3.3 the mean percentile scores are presented.

**Table 3.3.** The mean scores and standard deviations of the PMMA pre-test.
An initial difference exists between the control group and the treatment group, showing a moderately higher music aptitude for the control group. This difference is larger with regard to the rhythmical aptitude. Standard deviations of both the control and treatment groups are rather large, indicating the heterogeneity of the group. Clearly, Group A stands out with a high score (80th percentile or above) for both tonal and rhythmical tests. The standard deviation of this group was rather small in comparison to the other groups, indicating the homogenous nature of this group. However, a Mann-Whitney U statistic did not reveal a significant difference between the control and treatment group.

With regard to the development of the children’s music aptitude, differences can be found between the control (ID = 1 to 6) and intervention (ID = 7 to 12) groups. Table 3.4 shows the scores of both PMMA and IMMA when categorized as low (1), average (2) or high (3).

Table 3.4. Scores of both the PMMA (regular) and IMMA (italic) transformed into three categories: low score (1; 20th percentile or lower), average score (2; between 20th and 80th percentile), high score (3; 80th percentile or higher) (3).

In the control group, two children were administered the IMMA already from the second test and additionally the other children from the third test on. The sixth child of the control group also took the IMMA in the
post-test. In the experimental group, three children were administered the PMMA throughout the whole study, which indicates that they did not reach the 80th percentile of the PMMA (Gordon, 1986). Two children of the treatment group took the IMMA from the third test and one in the post-test. These results also show that children with a high score from the beginning, except for one child (ID=3), keep scoring high in the next tests, regardless which test (PMMA or IMMA) has been administered. Children with a low score in the pre-test show a different result. Some children (ID = 4,6,12) have an increased score; some children (ID = 8,10) show a more stabilized score. At the end of the nine months, most children (75%) were administered the IMMA test.

Although scores of the PMMA and IMMA cannot be compared, the shift from PMMA to IMMA indicates that development music aptitude progressed. Three children (25%) were still administered the PMMA. The mediocre scores of the three children (all part of the treatment group) who were administered the PMMA throughout the whole study suggest a rather low aptitude of these three children. Yet, the high standard deviation has to be taken into account. One of the three children had a high score (93) for tonal aptitude. Table 3.6 shows the mean and standard deviations of the post-test.

**Table 3.5.** Mean and standard deviations of the post-test. Because results of the PMMA and IMMA cannot be compared, scores are differentiated.
To investigate the influence of possible confounding variables, a correlation analysis was performed between the different measures and the P/IMMA scores. Findings indicated a positive correlation between singing behaviour and results of the tonal pre-test test, between the personality aspect ‘perseverance and results of the tonal pre-test, and between the personality aspect ‘concentration’ and scores on the rhythmic pre-test. A negative correlation was found between the personality aspects ‘anxiety’ and ‘irritability’ and the scores for the tonal pre-test. Due to the small sample size and the mixture of PMMA and IMMA scores in the post-test, it was not possible to perform a correlation analysis to investigate the relationship between the potential confounding variables (e.g. HME, personality) and the post-test.

4 Discussion and conclusion

In this study, a specific educational technology, the Music Paint Machine (MPM), was integrated in instrumental music instruction. The first aim of the study was to design good practices with the system. The weekly lesson preparations and the experience of using the system during instruction led to different practices (free exploration, guided exploration, direct instruction) that were carefully designed in function
of specific learning goals. They were tested and refined throughout the study.

The second aim of this study was to investigate whether instruction with the system could positively influence the developmental music aptitude of the children. It was hypothesized that providing instruction with the MPM would contribute to the establishment of a rich musical environment in which the development of music aptitude can be stimulated. We used the PMMA and IMMA (Gordon, 1986) to measure music aptitude. Although for most children a progress in the scores was found, some children’s scores showed a fluctuating effect and one child’s score even degraded continuously. No significant differences between the control and intervention group were found. However, in line with a study by Tai (2010) results suggested that singing behaviour has an effect on the scores of the PMMA. Results also suggested a relationship between facets of personality (e.g. concentration, perseverance) and the PMMA score. Personality has been linked before to music aptitude, in particular to Cattell’s personality factor intelligence (Schleuter, 1972). We believe that these results shed light on the occurrence of variables that might influence the scores on the aptitude test and as such urge caution with regard to the interpretation of its results. Another point of attention with regard to the use of these tests is the fact that results of the PMMA and IMMA cannot be compared (Gordon, 1986). Because most students progressed towards a PMMA score above the 80th percentile, they needed to do
the IMMA as post-test instead of the PMMA. As such and because of the limited number of participants, it was not possible to perform a correlation analysis to investigate the relationship between the potential confounding variables (e.g. HME, personality) and the scores for musical aptitude. Therefore, it remains inconclusive whether the changes that occurred in the children’s scores are due to instruction with the MPM. Further investigations are needed and the choice of the dependent variable and the instrument to measure it needs to be reconsidered.

Next to the limitations with regard to measuring the dependent variable, this study had other limitations. One limitation concerned the use of the system. Students were not able to use it at home. Arguably this affected the results. Being able to use the system at home might reinforce its influence on the development of music aptitude. A second limitation was the limited number of participants (n = 12). This affected statistical power. Nevertheless, we believe that working towards a full-blown intervention study was worth the effort. A third limitation concerned the system itself, which is a proto-type and sometimes didn’t work as expected. However, besides these limitations, the presented study has provided several insights and outcomes that are important for further research. First, conducting the study led to insights with regard to the focus of the study (effectiveness of the technology) and to the adopted method (design, measures). It became clear that it is necessary to focus on the
transformative impact of technology (see also: Beckstead, 2001; Kiesler, 1992). It also became clear that the control group design has many benefits in educational technology research but needs to be conducted in function of investigating processes (transformative impact) and not only products (amplicative impact).

Second, didactic practices have been designed that can be used to conduct future experiments. These practices are further developed in collaboration with other teachers through currently ongoing follow up studies. The further development of the MPM's software will entail the design of ready-to-use modules based on these practices.

Third, in this study video footage of all lessons (132 hrs) was made. A follow up observational study will be conducted in order to complement current data. This will allow studying how the integration of an educational technology such as the MPM affects the different components of instruction, i.e. student behaviour, teacher behaviour, student-teacher interaction and materials (Kennel, 2002). It is expected that different behavioural measures will also provide insights on the results of the repeated measurers used in this study.

To conclude, this study investigated the integration of an educational technology in a naturalistic instrumental music classroom setting. Although we knew in advance that the limited amount of children participating in this study (due to all kinds of practical concerns) could not be considered to be representative for our statistical tests, we
believe that our study went a step further than the lab experiments that are more commonly in this research domain. Dealing with the complexity of a real-life educational setting and with the requirements of the quasi-experimental design, this study has provided insights on methodology (design, measures, analysis) in music educational technology research. We believe that our approach holds a promising potential to conduct ecologically valid music education intervention studies.

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