Interacting with the Music Paint Machine: Relating the constructs of flow experience and presence

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ABSTRACT

In this paper we report on the results of an experiment on the experience of flow and presence while engaging with an interactive music system, the Music Paint Machine. This music system provides a game-like environment in which a musician can create a digital painting by playing an acoustic musical instrument, by moving the body in different directions, and by selecting colours using a pressure mat. The experiment aimed at getting a better insight into the possible relationship between flow experience and presence. Based on the definition of flow as a combination of the highest level of presence (presence-as-feeling) and a positive emotional state (Riva et al., 2004a), we hypothesized that presence has a predictive value for flow. Sixty-five musicians, both amateur and professional, participated in the experiment. Flow experience was measured with the Flow State Scale (Jackson and Eklund, 2004). Presence was measured with an in-house designed presence questionnaire. Results showed a significantly strong correlation between flow and presence. Moreover, the scores for presence significantly predicted the Flow State Scale, and explained a significant proportion of variance in the Flow State Scale. Furthermore, many significant associations were found between flow and presence variables, among which the most significant were the strong correlation (Spearman’s rank) between the naturalness of using the system and the Flow State Scale and between the feeling of non-mediation and the Flow State Scale.

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1. Introduction

In the field of music, interactive computer systems have become increasingly important in domains such as music performance and music education (e.g. Ng and Nesi, 2008; Finney and Burnard, 2009; Nijs et al., 2012). An important goal of these systems is to provide the user with an optimal experience, that is, an experience in which the user gets fully immersed, or deeply involved with the intended activity. In general, it is believed that the transparency of the used technology provides the basis for such an optimal user experience. This means that, when engaging with the interactive system, the user can focus on the goal (“what”), rather than being preoccupied with the means of how to achieve the goal (“how”) (e.g. Clark, 2008; Leman, 2007).

In recent work, attention has been devoted to embodied ways of engaging with music (Leman, 2007). In this approach, interactive systems are conceived as extensions or prolongations of the human body. The body is called the natural mediator because it mediates the connection between environment and experience. The technological extension is called the artificial mediator, because it provides access to an artificial (or digital) environment and its associated experience. Access to music is typically mediated by tools, such as music instruments, or interactive systems (from hyper-instruments to autonomous agents). From the viewpoint of embodied music cognition, the design of interactive systems should be aiming at the optimization of an embodied engagement with a musical environment that is not accessible without such a system. When successful, interactive systems form the basis for musical expression and musical meaning formation.

The Music Paint Machine is an example of a technology-enhanced learning tool that aims at providing a meaningful learning experience. As an interactive music system for music education, its ultimate goal is to optimize the learning process. Such technologies challenge pedagogical systems and offer a means to think about music education. Moreover, by integrating state of the art technologies, interactive music systems offer new possibilities for supporting the scientific endeavour to understand the processes that underlie an engagement with music. This leads to an increasing importance of user-oriented approaches in which the computer-mediated musical experience of both musicians and listeners are studied (Leman et al., 2010). However, to see whether and, if so, how interactive systems effectively support a direct involvement with music, the user experience of listeners and performers needs to be measured. This is often problematic, because subjective experience is often loosely defined and interchanging terms are used for phenomena that may be different (Nacke and Lindley, 2008).
A possible contribution to the conceptualization of subjective experiences is the investigation of the relationship between different existing constructs that aim at defining subjective experience. Two important constructs are flow and presence. Flow experience is an optimal experience in which the subject is completely immersed in an activity and fully concentrated on the task at hand. It is characterized by a sense of control and pleasure based on a subjectively experienced match between challenges and skills (Csikszentmihalyi, 2008). In contrast, the experience of presence is less agreed upon (Van Baren and Ijsselsteijn, 2004). Here we follow Riva and colleagues in their definition of presence as the non-mediated perception of successfully transforming intentions in action (Riva, 2008).

The relationship between flow and presence has been elaborated on in different studies. For example, presence has been conceived of as a kind of flow experience (e.g. Jacobson, 2002; Draper et al., 1998) or as a facilitator (Park and HWang, 2009), a prerequisite (Takatalo et al., 2002) or an enhancing factor for flow (Novak et al., 2000). Riva et al. (2004a) define flow as the result of the link between the highest level of presence-as-feeling, with a positive emotional state. However, there are only a few studies in which this relationship is investigated on the basis of empirical evidence. For example, Park and Hwang (2009) investigated how different types of immersion affect on online game addiction. These authors found that both presence and flow play a significant role in online game addiction. Their findings suggest that flow mediates the relationship between presence and online game addiction. Chertoff (2009) explored the relationship between flow and presence through measuring users’ reported flow and presence in a virtual environment that, based on its experiential design, was expected to stimulate flow. According to the findings of this author, flow neither enhances nor mediates presence. Rather it is the combination of the experiential design and flow that generates a larger general experience that shows a positive correlation with presence.

In the present paper, we report on an empirical study that uses an interactive system as an instrument to study the relationship between flow and presence. In particular, we present findings from a study with the Music Paint Machine, which is an interactive music system that allows musicians to make a digital painting by playing music on an acoustical instrument and by moving on a coloured pressure mat. As a first empirical step, we probed the experience of musicians (n = 65) when engaging with the system (Nijs et al., 2012, in press). The measurement of these experiences consisted of two separate questionnaires, namely, the Flow State Scale (Jackson and Eklund, 2004), and an in-house designed questionnaire on presence based on the Witmer & Singer Presence Questionnaire (Witmer and Singer, 1998; Witmer et al., 2005). The questionnaire-based measurement of flow and presence was used because we believe that the Music Paint Machine draws upon a unique relationship between musician and instrument, in which both flow and presence are highly relevant (Nijs et al., 2009, in press). Based on these measurements, our goal is to find relationships between the musicians’ experiences of flow and presence, while interacting with the Music Paint Machine.

This paper is structured as follows: first we introduce the Music Paint Machine, describing the system and relating it to the constructs of presence and flow (Section 2). An explanation of the system is given, followed by an elaboration of the role of presence in interacting with this system. Then we describe an empirical study that was conducted with 65 musicians (Section 3), followed by a conclusion (Section 4).

2. The Music Paint Machine

In this section we explain the system and the way it is related to flow and presence.

2.1. Explanation of the system

The Music Paint Machine is an interactive music system that allows a musician to make a painting on a computer screen by playing an acoustical music instrument and by moving on a coloured pressure sensing mat. In this way, the musician engages in an interactive loop between playing music and moving on the one hand and the visual output on the other hand.

The hardware and the software of the system are developed in our research centre through a spiral collaboration between researchers with backgrounds in music education, computer science and interactive visual art, and an engineer. An elaborated description of the design methodology and the hardware and software of the system is presented in Nijs et al. (2012, in press). Here we shortly describe the system as presented in Fig. 1.

Different hard- and software components such as for example inertial sensors and a Max/Msp1 pitch-tracking object are used to monitor the musician’s playing. The music that is played and the movement of the musician’s torso and feet are tracked, analyzed and mapped to the visual parameters that constitute the digital painting. An overview of the mapping is presented in Fig. 2.

An important aspect of the Music Paint Machine’s mapping (from audio and movement to visual) is determined by the way in which the music instrument and the musician are both united into a higher order entity (Nijs et al., 2009, in press). This unity of musician and instrument becomes the controller of an interactive system that provides feedback on a screen. In contrast to many existing interactive music systems (e.g. Wii Music, Guitar Hero), the acoustical music instrument is not replaced by an electronic device that is either completely different (e.g. the Wii remote) or either a simplified version of existing acoustic instruments (e.g. the guitar of Guitar Hero).

2.2. The Music Paint Machine, flow and presence

The Music Paint Machine provides a multimodal environment that mediates the musical experience of the musician. While “painting with body and music”, the musician engages in an interactive loop between body movement, sounding music, and visual output. In this way, the system constitutes a particular activity that shapes the experience of the musician. As a learning tool, the Music Paint Machine aims at supporting the development of musical creativity, at the stimulation of an embodied understanding of music and at the development of an intimate relationship with the musical instrument (Nijs et al., 2010, in press).

Probing the musicians’ experience with questionnaires is an important part of the iterative design process that steers the development of the Music Paint Machine into a practice-based technology-enhanced learning tool (Nijs et al., in press, 2012). After all, it is assumed that the possible effectiveness of this interactive system depends on an important degree on its ability to provide learners with a powerful learning environment that stimulates learning by invoking an optimal experience (e.g. Shernoff and Csikszentmihalyi, 2009).

2.2.1. The Music Paint Machine and flow

The three pedagogical goals that underpin the design and use of the Music Paint Machine are related to the construct of flow.

The first pedagogical goal concerns the development of musical creativity. Optimal experiences such as flow have often been acknowledged as fundamental to the development of (musical) creativity (e.g. Addessi and Pachet, 2005; Csikszentmihalyi, 2008). In contrast, the experience of presence is less agreed upon (Van Baren and Ijsselsteijn, 2004). Here we follow Riva and colleagues in their definition of presence as the non-mediated perception of successfully transforming intentions in action (Riva, 2008).
The Music Paint Machine aims at inducing such optimal experiences by providing students with an immersive experience of playing with musical parameters, body movements and visualizations. By means of explorative sessions and specific exercises that are integrated into a learning path, students are stimulated to explore and experiment with music in order to develop a creative use of the different musical parameters namely loudness, duration, pitch and articulation. It is assumed that the occurrence of a flow experience while interacting with the Music Paint Machine will invoke a sense of playfulness with the different musical parameters. This is expected to have a positive effect on musical creativity. Indeed, playfulness in general has been related to flow experience (e.g. Webster et al., 1993; Woszczynski et al., 2002), and playfulness with musical parameters has been considered an important aspect of musical creativity (e.g. Deliège and Wiggins, 2006). Moreover, learning to be playful with musical parameters is linked with learning how to improvise (Kratus, 1991). Improvisation can be considered as an essential component in the development of musical creativity (e.g. Strobbe and Van Regenmortel, 2010).

The second pedagogical goal concerns an embodied musical understanding of which we believe that it is stimulated by flow experience. Such an understanding is said to originate from the ability to feel the music from within (e.g. Bowman, 2004), that is, through the bodily sensing, feeling and experiencing of the musical sounds (Shepherd, 2002). It is assumed that, through a process of corporeal imitation, learned schemata of action-perception couplings are used to transform patterns of sound into corporeal articulations (Bowman, 2004; Leman, 2007). In this way it becomes possible to corporeally resonate with the music and to rely on the corporeal – basis to give meaning to the music and to develop musical understanding. Such corporeal attunement with the music is characteristic for an embodied interaction with music. It is an experience in which the musician participates in a direct and engaged way in the musical environment he or she creates throughout a performance (Dourish, 2004). Participating in this way in the musical environment is based on a direct perception of the musical stimuli and on a skill-based coping with the challenges that arise from the complex interaction within this environment (Nijs et al., 2009, in press). Direct perception and skill-based acting are two sides of one coin and can be related to several dimensions of flow experience, namely a balance between the perceived challenges and one’s skills, immediate feedback, the sense of control and the merging of action and awareness. The Music Paint Machine is designed to create an environment that, through the facilitation of direct perception and skill-based acting, stimulates an embodied interaction. While the digital painting is meant to capture the focal awareness of the musician, many aspects related to musical parameters may reside in subsidiary awareness and become elements of tacit knowledge (Polanyi, 1958). Embodied understanding here derives from what Polanyi calls “indwelling”, that means, the active engagement of the body with the factors that comprise our subsidiary awareness. Flow experience, devoid of disconnected observation and control, is rather characterized by an inhabited interaction in which a person is so focused on the task at hand that action and awareness merge. We believe that his may facilitate the indwelling, or knowing from within, and thereby may invoke a powerful implicit learning process.

The third pedagogical goal concerns the establishment of an optimal relationship with the music instrument (Nijs et al., 1990).
and challenges, the immediate and unambiguous feedback, and to three flow dimensions, namely, the balance between skills and challenges and accordingly a positive emotional condition. Therefore particular attention has been devoted to three flow dimensions, namely, the balance between skills and challenges, the immediate and unambiguous feedback, and clear goals (Chen et al., 1999). The mapping of pitch to vertical position on the screen can be adapted to the ranges of notes a musician can play. Similarly, stroke thickness can be adapted to the loudness range of the musician. In this way the system enables the balance between skills and challenges and accordingly a skill-based playing. Next, the immediate and unambiguous feedback on the screen is the result of the musician’s playing (sound and movement). It is assumed that the straightforward nature of the mapping that underlies the transformation from sound and movement into the visual domain might stimulate the direct perception of task-related stimuli. Finally, it is possible to define one’s own goals (e.g. merely drawing a series of lines in one colour, drawing a complex pattern of colours and geometrical figures or drawing a concrete image such as a boat on the sea) or to perform specific drawing tasks, provided by, for example, a teacher. In both cases, the system allows activities that are characterized by clear goals. It is assumed that the abovementioned system characteristics might facilitate an embodied interaction and induce a flow experience. Although the measurement of flow experience may capture an important aspect of the learners’ experience, we believe that the construct of flow may not be sufficient to capture the mediating role of the body and its technological extensions. It is assumed that the measurement of presence might contribute in a significant way to understanding the interactive processes and their bodily basis, especially when engaging with an immersive multimodal interactive music system such as the Music Paint Machine.

2.2.2. The Music Paint Machine and presence

Measuring the sense of presence while engaging with an interactive music system informs on the degree to which one is bodily engaged during the performance of a task. It is assumed that the sense of presence is rooted in an unconscious mechanism, namely presence-as-process, which allows controlling behaviour on the basis of an unconscious differentiation between the inner and outer world (Riva et al., 2004a,b). According to Riva et al. (2004b), presence is a layered process that relies on a coherent collaboration of bodily sensations, perception and cognition to keep attention focused on the activity. Three layers, called proto presence, core presence, and extended presence are hierarchically structured, following the hierarchical relationship of Damasio’s levels of self (Damasio, 1999). Each layer deals with the separation between the internal (self) and external (non-self) world and is hypothetically related to a level of consciousness. Proto presence is about the bodily being in the world (self vs non-self) and is only achieved when the self is able to use the body for enacting intentions in the external world. Core presence is related to the differentiation between planned actions and actual actions (self vs present external world). At this level, presence is only achieved when it possible to select and respond to task-related elements in the environment. Extended presence is related to the significance of the activity for the self (self relative to the present external world).

In view of an embodied apprehension of flow, it is instructive to consider proto presence in more detail. The more the internal world (self) is focused on the body, the more it is different from the external world. Being in the body results from unconsciously experiencing the self as being able to use the body for coping with the challenges in the external world. At this level of presence, the sensorimotor coupling of action and perception plays a defining role. Proto presence occurs when the coupling between actions and perception is perceived as matching, that is when the outcome of an action satisfies the anticipated results. This is always accompanied by the bodily sensation of something affecting the border between self and non-self. Importantly, whatever has the most impact on the body will be the focus of this level of presence, and it will therefore be experienced as non-self. According to Riva et al. (2004a,b) a maximal sense of presence, namely, presence-as-feeling or the feeling of being “there”, occurs when the content of every level of consciousness is the same, namely the external world (“there”).

To better understand how presence is related to a musical experience with the Music Paint Machine, it is necessary to examine in more detail the nature of the processes that underlie music making. Through his actions, the musician creates a musical reality that can be considered as the actualization of an imaginary world, a virtual reality that is constituted by the musician’s musical intentions and representations. For the musician, creating this musical reality is characterized by the coupling of two representational spaces (Leeman, 2007).

The first representational space is called the “inner space”, or the representation of the world “inside us”. It contains a repertoire of gestures, that is, traces of motor activity in memory that relates to the sensing and execution of movements in function of goals. With regard to music, these gestures are derived from previous

experiences with music through, for example, rehearsals and previous performances. A distinction is made between gross-motor gestures and fine-motor gestures. The gross-motor gestures have a social communicative basis, and they are required to play music in an expressive way, so that the music can affect other persons. For example, they can be larger sequences of notes that address a particular emotional quality. The fine-motor gestures have a sensorimotor basis. These gestures rely on the repertoire (because they are rehearsed), but they are also largely dependent on a direct and immediate feedback from the environment. They are required to play a specific musical instrument, for example, to control the fingers and the lip tension in a coordinated way in order to play a single note on the trumpet.

The second representational space is called the “outer space”, or the representation of the world “outside us”. This space is constituted by incoming sensory information from the interaction with the environment. It is based on the feedback of the musical instrument, the sonic structure of the music, the audience, the acoustics of the room, and other possible constituents.

The coupling of both spaces allows perceiving the musical reality from the viewpoint of intentional actions. Based on the anticipatory model and the incoming sensory information, actions are monitored and evaluated in relation to goals.

Presence is exactly this process that monitors actions in function of an intended outcome. A maximal sense of presence occurs when the three layers of presence are integrated and all levels of consciousness share the same content. This means that, to immerse in the musical reality and experience the sense of presence, the musician must be able to attune to the music at the level of bodily sensation, perception and cognition. However, given the complexity of the musical environment and the fact that a musician has to deal with a series of competing signals that arise from the interaction with the different elements of the musical environment, this is not obvious. Whatever stimulus has the strongest impact on the body, it will determine the content of proto consciousness and influence proto presence. Ideally, the musician can immerse in the music through a bodily attunement with the music. In this case the musician can focus on signals from the music and deal with the musical goals (interpretation, expression).

This implies that the content of core consciousness will be musical. As long as the music unfolds in accordance with the musical goals, this will not change and core presence will be dealing with the signals from the music. However, when the mediating artefacts such as the musical instrument have the strongest impact (e.g. because of technical difficulties, a wrong note or a squeak), the musician instead has to be preoccupied with the means to realize these goals (executive strategies) will shift attention from the music to the mediating artefact that caused this shift. It will no longer be possible to keep core consciousness focused on the music and immerse in the musical reality. Instead the musician will have to attend to the signals that arise from the interaction with the mediating artefact.

The above theory was regarded as highly relevant for the Music Paint Machine. By transforming movement and sound into a visual output, the Music Paint Machine creates an “augmented” musical environment and thereby affects a musician’s involvement in this environment at the level of sensation, perception, and cognition. We assume that the Music Paint Machine affects the musician’s sense of presence while painting through movement and sound.

First, the auditory-motor loop that underlies the process of making music is augmented with the visual modality through which both auditory and motor aspects are represented on a computer screen. The visual feedback augments the created musical world or auditory reality with a visual output (“the ‘painting’”). Because what is happening on the screen is the result of the musician’s actions, the visual output provides extra sensory information that enables the musician to monitor whether the intentions in action are successfully transformed. Starting from the viewpoint that presence is a form of monitoring of action and experience that enables the musician to discriminate between self-determined and world-determined changes in incoming sensory information (Riva et al., 2006; Russell, 1996), we assume that the Music Paint Machine affects core presence through the feedback it provides. Moreover, using the system requires specific movements and thereby engages the body in ways that can be unusual with regard to “normal” playing. Using the feet to choose the colours or twisting and bending the torso to respectively choose drawing direction and influence colour transparency, leads to additional movement patterns. It is assumed that this might stimulate a bodily focus on the task and thereby affect proto presence.

Second, and related to the monitoring of one’s actions, using the Music Paint Machine may affect the creation of action perception couplings. These couplings are crucial for determining the extent to which intentions are successfully enacted, so that the sense of presence can occur (Zahorik and Jenison, 1998). Musicians always have certain goals in mind (e.g. making crescendo) but sometimes, unconsciously, fail to realize this goal in the sound energy (increasing amplitude). Failure might be attributed to listening skills or to attention, but when this repeatedly happens, a “wrong” action perception coupling can be established. Adding visual information about the musician’s actions might point at this unnoticed discrepancy between intended and actual results of sound production by providing additional – inconsistent – information. The visual feedback informs the musician that certain intentions are not successfully enacted. Accordingly the musician might correct his or her actions to make all sensory information consistent. Moreover, this process of adapting one’s actions in order to render the auditory, kinaesthetic and visual feedback consistent can become an unconscious monitoring process. In this way, the Music Paint Machine may contribute to the establishment of the necessary fine-tuned action perception couplings that constitute the musician’s interaction with the musical world and that underlie the musician’s fine-grained control over the instrument. Again, we assume that this may affect the sense of presence through the stimulation of both proto and core presence.

Third, by introducing body movement and sound as controllers of the system, the computer screen not only serves as a mirror of a performance (sound and movement) but, additionally, functions as a digital painting canvas that appeals to the musician’s creativity and imagination to create a digital painting. In this way, the Music Paint Machine affects the goals of the musician, who in addition to his musical goals can try to realize effects in the visual domain. It is assumed that this invitation to be creative might affect the meaningfulness of the activity for the musician and thereby contribute to extended presence.

3. Empirical study

3.1. Method

3.1.1. Participants

This study involved 65 musicians, both professional and amateur. They were recruited by advertisements on social network sites and in different music schools. Furthermore, a website was created to inform possible participants on the experiment and to organize the sessions. All participants were informed about the procedure and participated on a voluntary basis.

Two-thirds (66%) of the participants were female. Their average age was 23 years and about two thirds (65.6%) of them were under the age of 25. Participants’ main instruments were flute (27.7%), clarinet (20%), saxophone (18.5%) and violin (13.8%) and other
instruments (20%). They have been playing their instrument for 1–9 years (58.5%) or longer (41.5%). One fifth of (20%) the participants were professional musicians and teaching in a music school. The other participants were amateur musicians, most of them (75%) still following instrumental lessons.

3.1.2. Materials and setting

The material that was used for the experiment included the Music Paint Machine and its components (i.e. coloured pressure sensing mat, computer, motion sensor, clip on microphones). The computer screen was projected onto the classroom wall or screen using a beamer. Two digital video cameras were used: one videotaped the musician, the other the screen. Experiments were mostly conducted in music schools, involving 63% of the participants. Amateur musicians who no longer followed instrument lessons and therefore were not able to attend the sessions in schools, and most teachers tested the Music Paint Machine at the research lab. Apart from the different locations, material, setup and procedure were identical.

3.1.3. Procedure and task

The experiment consisted of three sequential parts: (1) completing a background and personality questionnaire, (2) performing a task with the Music Paint Machine, and (3) completing a questionnaire that probed, in the first place, the participants’ subjective experience while performing the task and, in the second place, the way they evaluated the didactic potential of the system.

In the first part of the experiment, a background questionnaire was administered to the participants prior to the testing. They were requested to answer general questions related to age and gender. They also had to specify, using a non-forced seven-point Likert scale, to what extent they agreed with statements about their musical background and their computer use.

In the second part of the experiment, participants performed a task with the Music Paint Machine. Firstly, they were shortly informed on how to use the system. In this way they could learn about its mapping. This step also included the calibration of the system in accordance with the skills of the player, such as the adaptation of the screen resolution to the range of notes the participants could play or the adaptation of the brush size to the dynamical range of the participant’s playing capabilities. Finally, the participant performed a task, formulated as follows: “Please create one or more paintings on the screen, by playing music with your instrument or for developing improvisation skills.” It was emphasized that they could draw whatever they wanted, whether figurative or abstract and that the label of bad or good was not applicable to the paintings or the music played. Participants were given ten minutes to perform the task. This part of the experiment was videotaped.

During the third part of the experiment, participants were asked to complete a questionnaire consisting of three sets of questions that aimed at (1) measuring the quality of their subjective experience while playing music and making a painting with the Music Paint Machine and (2) learning about the way the participants evaluated the didactic potential (dependent variables) of the system after having experienced playing with it (independent variable). The first set comprised the questions of the Flow State Scale (Jackson and Eklund, 2004). The second set of questions was designed in-house on the basis of the theoretical presence determinants as defined by Witmer and Singer (1998). The third set comprised questions related to the role of the visual feedback, the possible supportive role of the system for learning to play an instrument or for developing improvisation skills. Although the last set of questions is not directly related to the quality of the subjective experience, the way participants evaluate the didactic potential of the system is related to the meaningfulness of the experience, which is assumed to play a role in the experience of presence (Witmer and Singer, 1998).

3.1.4. Measures

3.1.4.1. The Flow State Scale questionnaire (FSS). The Flow State Scale (Jackson and Eklund, 2004) probed the participants’ experience with the system by means of 36 questions that can be grouped into nine dimensions of flow experience (Csikszentmihalyi, 1990). These nine dimensions can be grouped into antecedents, characteristics and consequences (Chen et al., 1999). The scores of these dimensions are combined to measure an overall scale (FSS) that represents the flow state of the participant (see Table 1). The original Flow State Scale questionnaire was translated into Dutch. The translation procedure was as follows: first, two professional translators and two bilingual researchers, familiar with the theory on flow and experienced in questionnaire design, worked independently to translate the original English version into Dutch. Second, a third bilingual researcher, also familiar with the theory on flow and experienced in questionnaire design, combined these versions into one version. Finally, questions were translated back into English and adjustments were made. To allow for more variability in the responses and to keep the same scale granularity for both the flow and presence questionnaires, items were measured on a non-forced seven-point Likert scale instead of the usual five-point Likert scale. Answers ranged from “completely disagree” to “completely agree”.

3.1.4.2. In-house designed presence questionnaire (PSS). Our presence questionnaire is a first attempt to develop a presence questionnaire in the domain of interactive music systems. After examining of different existing questionnaires (see http://www.presence-research.org/Questionnaires.html), we decided to take the Presence Questionnaire (PQ), developed by Witmer and Singer (1998), as our starting point. This was done for several reasons. First, this questionnaire was designed to be valid across

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Flow dimensions and categories as elaborated by Csikszentmihalyi (2008).

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3.1.5. Statistical analysis

When using the Music Paint Machine in its explorative modus, an interactive loop between playing music, moving and drawing completely agreed. The media and content. Second, the theoretical factors the PQ was elaborated on, namely control, distraction, sensory experience and realism of the system (see Table 2), were evaluated as appropriate factors to define the interaction with the Music Paint Machine.

Third, despite Slater’s comments to the validity of the PQ (Slater, 1999), the fact that the PQ questions measures people’s responses to various aspects of the system was not seen as a disadvantage, since the experiment also aimed at finding out what characteristics of the system are determining aspects in relation to the experience of presence. It is assumed that the way in which people feel or experience their own responses to the system, determines the possible experience of presence. After all, through the activity it initiates, the system creates a specific environment and thereby mediates its user’s musical experience on the basis of its specific characteristics. The ability to respond to these characteristics determines the degree to which one is able to successfully transform intentions into actions with the system. By asking participants to report on their perceptions of the environment and on their interactions within this environment, the questionnaire attempts to capture a multitude of variables that influence the experience of presence.

Because not all of the items of the Witmer & Singer Presence Questionnaire were suitable to the particular conditions of the experiment (e.g. “How compelling was your sense of moving around inside the virtual environment?”), we selected the appropriate items and adapted them to suit the particular condition of interacting with the Music Paint Machine. In order to increase the identification of the participants with their answers and to give them the opportunity to reflect on their personal experience and perceptions, statements were mainly formulated from a first person perspective. In Table 3 we present the Witmer & Singer Presence Questionnaire. Participants were asked to rate their (dis)agreement with the statements on the basis of a non-specific drawing or musical tasks. In this paper we report on the results with regard to flow, presence and their possible relationship.

3.1.5.1. Flow. First, internal consistency was tested for with the Cronbach Alpha test. Second, scores for the nine flow dimensions and Flow State Scale were calculated following the procedure as prescribed in the manual of the Flow State Scale (Jackson and Eklund, 2004). Additionally we calculated scores for the three stages of flow as outlined by Chen et al. (1999). Third, a descriptive analysis was performed on both measured variables, namely the score for individual items (e.g. enjoyment, focus of attention) and calculated variables, namely the mean score for groups of items (flow dimensions) and total scores (Flow State Scale).

3.1.5.2. Presence. For the in-house designed presence questionnaire, a similar procedure as for the Flow State Scale was followed. First, internal consistency of the questionnaire was tested using Cronbach’s alpha. Second, a score for presence was determined by calculating an overall mean score (PSS). To calculate this overall presence score, the scores of certain items (e.g. “While performing, I paid attention to my movements”, “While performing, I paid attention to what happen around me”, “Using this system requires a great mental effort”) were reversed to obtain a score that is representative for the sense of presence (e.g. a high score on cognitive load would increase the overall score of presence but is not representative for the sense of presence). Third, a principal component analysis was used to extract determining factors and to allow for an analysis on different levels (items, factors, scale) as was done for the Flow State Scale.

3.1.5.3. Flow and Presence. To test for a possible relationship between flow and presence, several statistical procedures were followed to get a detailed view on the relationship between the constructs of flow and presence. In our analyzes, we opted for a strong significance level (\(\alpha = .001\)). First, a simple linear regression was performed on the FSS (dependent variable) and the PSS (independent variable). If flow is defined as a combination of presence and a positive emotional condition, then it assumed that the PSS has a predictive value with regard to the FSS. Second, a multiple linear regression with the FFS as independent variable and the extracted presence components as dependent variables. Here the goal is to scrutinize how different aspects of presence are related to the state of flow. Third, we performed a canonical correlation analysis to investigate how specific aspects of flow are related to specific aspects of presence and to look for common features.

3.2. Results

3.2.1. Flow

A Cronbach’s alpha test \((\alpha = .921)\) confirmed the internal consistency of the questionnaire.

The scores of the Flow State Scales varied from 3.44 to 6.78 on a seven-point Likert response format from completely disagree to completely agree. The moderately high overall mean (5.15, \(SD = .74\)) indicates that the Music Paint Machine is likely to have the potential to turn the experience of playing music, moving and drawing, into an optimal or flow experience. Descriptive analysis on the level of flow dimensions showed a moderately high score for dimension 1 (challenge/skill balance). The dimensions 5 (autotelic experience) have the highest score. These results indicate that the Music Paint Machine has the potential to elicit a fun experience that fully captures the musician’s attention. In Table 4 we present an overview of the scores for the Flow State Scale and the different dimensions and categories.

<table>
<thead>
<tr>
<th>Presence factors</th>
<th>Degree of control</th>
<th>Immediacy of control</th>
<th>Anticipation of events</th>
<th>Mode of control</th>
<th>Physical environment modifiability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sensory factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Distraction factors</strong></td>
<td>Isolation</td>
<td>Selective attention</td>
<td>Interface awareness</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Realism factors</strong></td>
<td>Scene realism</td>
<td>Information consistent with objective world</td>
<td>Meaningfulness of experience</td>
<td>Separation anxiety/disorientation</td>
<td></td>
</tr>
<tr>
<td>Witmer &amp; Singer PQ</td>
<td>Nij et al. presence questionnaire</td>
<td>Label</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>----------------------------------</td>
<td>-------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. How much were you able to control events?</td>
<td>1. I felt like I could do what I wanted</td>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. How responsive was the environment to actions that you initiated or performed?</td>
<td>2. The system responds well to what I do</td>
<td>Systems responsiveness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. How natural did your interactions with the environment seem?</td>
<td>3. It felt natural to use the system</td>
<td>System naturalness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. How much did the visual aspects of the environment involve you?</td>
<td>4. While performing, I paid attention to the screen</td>
<td>Attention to screen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. How much did the auditory aspects of the environment involve you?</td>
<td>5. While performing, I paid attention to the music</td>
<td>Attention to music</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. How natural was the mechanism which controlled movement through the environment?</td>
<td>6. The mapping between my actions and the effect they generated, felt natural (e.g. play loud = thick line, play soft = thin line, pitch to vertical position on the screen)</td>
<td>Natural mapping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. How compelling was your sense of objects moving through space?</td>
<td>7. “The things I had to do (move feet, turn torso) deviate too much from the normal way of performing on my instrument and playing music”</td>
<td>Unusual actions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. How much did your experiences in the virtual environment seem consistent with your real world experiences?</td>
<td>8. “I could predict the effect of my actions”</td>
<td>Anticipation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Were you able to anticipate what would happen next in response to the actions that you performed?</td>
<td>9. I succeeded to draw in different ways (thin and thick lines, long and short lines, different colours, change drawing direction, . . .)</td>
<td>Varied drawing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. How completely were you able to actively survey or search the environment using vision?</td>
<td>10. While performing, I paid attention to my movements</td>
<td>Attention to movement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. How well could you identify sounds?</td>
<td>11. While performing, I paid attention to my musical instrument</td>
<td>Attention to instrument</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. How well could you localize sounds?</td>
<td>12. While performing, I paid attention to the pressure mat</td>
<td>Attention to mat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. How well could you actively survey or search the virtual environment using touch?</td>
<td>13. While performing, I paid attention to the movement sensor</td>
<td>Attention to sensor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. How compelling was your sense of moving around inside the virtual environment?</td>
<td>14. While performing, I paid attention to what happened around me</td>
<td>Attention to surroundings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. How closely were you able to examine objects?</td>
<td>15. I was able to concentrate on the task (make a painting) without being preoccupied with the mechanisms that enable the making of a painting (pressure mat, musical instrument, movement sensor, computer)</td>
<td>Non-mediation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. How well could you examine objects from multiple viewpoints?</td>
<td>16. Using this system requires a great mental effort (I need to think a lot when using it)</td>
<td>Cognitive load</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. How involved were you in the virtual environment experience?</td>
<td>17. I needed some time to get used to the system before I understood how to use it</td>
<td>Get used</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. How much delay did you experience between your actions and expected outcomes?</td>
<td>18. The system requires a long learning phase before being able to use it spontaneously</td>
<td>Long learning phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. How well could you move or manipulate objects in the virtual environment?</td>
<td>19. This system stimulates different senses</td>
<td>Multimodality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. How well could you examine objects?</td>
<td>20. The system stimulates me to be creative with musical parameters (loud-soft, short-long, articulation, . . .)</td>
<td>Creativity</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>21. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>22. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>23. How much did the control devices interfere with the performance of assigned tasks or with other activities?</td>
<td></td>
<td></td>
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<tr>
<td>24. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>25. How completely were your senses engaged in this experience?</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>26. To what extent did events occurring outside the virtual environment distract from your experience in the virtual environment?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>27. Overall, how much did you focus on using the display and control devices instead of the virtual experience and experimental tasks?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>28. Were you involved in the experimental task to the extent that you lost track of time?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>29. How easy was it to identify objects through physical interaction, like touching an object, walking over a surface, or bumping into a wall or object?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>30. Were there moments during the virtual environment experience when you felt completely focused on the task or environment?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>31. How easily did you adjust to the control devices used to interact with the virtual environment?</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>32. Was the information provided through different senses in the virtual environment (e.g., vision, hearing, touch) consistent?</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
The second component, accounting for 13.8% of the variance, consisted of items that measure the perceived quality of actions. These items expressed the degree of control, the immediacy and the mode of control, the perceptual non-mediation and the consistency of the actions with normal instrument playing. Their clustering suggests that this component is related to agency. The large percentage of the variance that is explained by this component points to the fact that the sample size is in principle not large enough to perform a factor analysis. We still chose to perform it, based on the KMO value and the values of the communalities. The Kaiser–Meyer–Olkin measure verified the sampling adequacy for the analysis, KMO = .638. According to Field (2009), this is a mediocre but acceptable result. However, because not all KMO values for individual items exceeded the acceptable limit of .5 (Field, 2009), the same factor analysis was performed on a reduced number of items. Five items that had an individual KMO value below .5 were excluded. These items were: I succeeded to draw in indifferent movements captured the player’s attention. This component accounted for 6.7% of the variance.

After exclusion of these items, the Kaiser–Meyer–Olkin measure verified the sampling adequacy for the analysis, KMO = .753. Individual KMO values were all above .5. Bartlett’s test of sphericity X² (120) = 311.281, p < .001, indicated that correlations between items were sufficiently large for PCA. Communalities were rather high (M = .685, SD = .12).

An initial analysis was run to obtain Eigen values for each component in the data. Five components had Eigen values over Kaiser’s criterion of 1 and together explained 68.46% of the variance. Table 5 shows the factor loadings after rotation with an absolute value greater than .4.

The first component, accounting for 29.7% of the variance, consisted of items that measure the perceived quality of actions. These items expressed the degree of control, the immediacy and the mode of control, the perceptual non-mediation and the consistency of the actions with normal instrument playing. Their clustering suggests that this component is related to agency. The large percentage of the variance that is explained by this component points to the importance of the sense of agency.

The second component, accounting for 13.8% of the variance, clusters items related to cognitive load and to short and long term learning process required to interact with the system. This cluster therefore seems to represent learnability. The third component consisted of four items and accounted for 9.5% of the variance. Items were related to the experience of the mapping of the system as natural, to the ability to predict the outcomes of one’s actions, to the multimodal nature of the system and to the system’s ability to stimulate creativity.

The fourth component, accounting for 8.1% of the variance, consisted of two items both related to used mechanisms, namely the musical instrument and the movement sensor.

The fifth and last withhold component also consisted of two items, namely the degree to which musical instrument and the movements captured the player’s attention. This component accounted for 6.7% of the variance.

Since both the fourth and the fifth component consisted of only two items, they are considered as rather weak and unstable components (Costello and Osborne, 2005; Velicer and Fava, 1998). This was also shown in the reliability analysis of the components. The first three components had reliability above the α cut-off value of .70, the fourth and fifth components had negative, and therefore nonsensical, values.

To summarize, the principle component analysis led to the extraction of three defining components, explaining 53.5% of the variance:

1. **Agency**: this first component is related to the way the musician perceives his or her own actions while interacting with the Music Paint Machine. Does it feel natural to use the system? Do the used mechanisms require attention? Were actions accompanied by a sense of control?

2. **Learnability**: this component is related to how quickly a musician feels competent to use the system. Does he or she needs a long time to get used to the system? In other words, how fast can he or she learn to use the Music Paint Machine in such a way that what he or she wants is what he or she actually gets.

3. **Interface Quality**: this component is related to characteristics of the medium. Does it react adequately to the musician’s actions? Does it use a straightforward and naturally felt mapping from action to outcome?

However, next to these extracted components, the items that were excluded from the principle component analysis still have to be taken into account. Exclusion, based on their KMO value, indicates the impossibility of meaningfully clustering these variables into a component but makes no statement about their significance with regard to the overall scale, the PSS. A Spearman
correlation test indicated that only one of these variables was significantly correlated with the PSS, namely varied drawing, $r_s = .424$, $p < .001$.

### 3.2.3. Presence and flow

To test for the relationship between flow and presence, several statistical methods were used.

First, analysis was performed on the two overall scores (FSS and PSS). Based on the definition of flow as a combination of the highest level of presence and a positive emotional condition (Riva, 2005), we hypothesized that a strong positive correlation exists between presence (independent variable) and flow (dependent variable). Since both presence and flow are always a matter of degree, it is expected that the higher the score for the presence state scale is, the higher the score for the Flow State Scale will be. After a Shapiro–Wilkinson normality test, a bivariate correlation analysis (Pearson’s $r$) was run on the scores for the flow and presence state scales. A strong correlation, $r = .598$, $p < .001$, between both variables was found.

Second, after the inspection of the corresponding scatter plot, a simple linear regression was performed to further assess the relationship between both scales and to test the hypothesis that presence predicts flow. The Presence State Scale significantly predicted the Flow State Scale, ($b = .805$, $t (61) = 5.823$, $p < .001$) and explained a significant proportion of variance in the Flow State Scale, $(R^2 = .357, F(1, 61) = 33.9, p < .001)$.

Third, a multiple linear regression analysis was performed on the extracted presence components (Agency, Learnability, Interface Quality) and the FSS. The results of the regression indicated the three predictors explained 61.3% of the variance $(R^2 = .631, F(3, 61) = 34.79, p < .001)$. It was found that Agency significantly predicted the FSS $(b = .60, p < .001)$, as did Interface Quality $(b = .314, p < .001)$. The Learnability component did not have a significant predictive value $(b = -.069, p = .443)$.

Fourth, to determine the nature of the relationship between the underlying structures of both the constructs of flow and presence, a canonical correlation analysis was performed between the extracted presence components and the flow dimensions.

Tests of dimensionality for the canonical correlation analysis, as shown in Table 6, indicate that one of the three canonical dimensions is statistically significant at the .001 level. This dimension had a canonical correlation of 0.913 between the sets of variables. Table 7 presents the standardized canonical coefficients and the correlations between (1) the dependent variables (flow) and covariates (presence) and (2) the canonical variables.

For the flow dimensions, the extracted canonical dimension is most strongly correlated with the dimension Merging of action and awareness ($-.92$) and the dimension Sense of control ($-.95$). With regard to the presence components, Agency ($-.92$) and Interface Quality ($-.60$), were the dominating variables for the extracted canonical dimension.

Fifth, a correlation analysis (Spearman’s $r$) was performed between the flow variables and the presence items (varied drawing, attention to screen, attention to music, attention to mat, attention to surroundings) that did not cluster and therefore were excluded from the principle component analysis. The strongest correlation was found between the fact that a participant paid attention to the screen and was focused on the task at hand, $r_s = .518$, $p < .001$. Participants’ paying attention to the music significantly correlated with the fact whether they experienced a balance between skill and challenge, $r_s = .438$, $p < .001$. Attending to the music was also significantly correlated with having an autotelic experience, $r_s = .355$, $p < .001$. Furthermore, believing to have succeeded in drawing something in different ways was significantly correlated with having an autotelic experience, $r_s = .333$, $p < .001$. This was also the only item that correlated significantly, at the .001 level, with the FSS, $r_s = .328$.

Noteworthy to mention, in view of a detailed account of the relationship between aspects of presence and flow are the correlations between the FSS and the naturalness of using the system, $r_s = .721$, $p < .001$, and between the FSS and the perceptual non-mediation, $r_s = .650$, $p < .001$.

### 3.3. Discussion of the results

The present study aimed at probing the subjective experience of the participants and examined the relationship between flow and presence in the context of interactive music systems. In what follows we discuss the limitations of our in-house designed presence questionnaire (3.4.1), on how are findings are related to the original questionnaire (3.4.2), on the found relationship between flow and presence (3.4.3), on the use of the constructs of flow and presence in the context of interactive music systems (3.4.4) and on how presence and flow relate to embodiment (3.4.5).

#### 3.3.1. The presence state scale questionnaire

While the Flow State Scale questionnaire was found suitable in the context of interactive music systems, we found no presence questionnaire that could be used in this particular context. Therefore we designed our own questionnaire, based on the theoretical elaborations of presence and starting from items of the PQ (Witmer and Singer, 1998; Witmer et al., 2005). Although many of the findings suggest consistency with theoretical assumptions, the reliability of this questionnaire ($z = .64$) could be improved. Further development and optimization of the questionnaire is challenging but we believe it might contribute to the further elaboration of a user-oriented approach in the field of embodied music cognition (see also: Leman et al., 2010). Items in this questionnaire that were based on the PQ items must be partially revised, mostly concerning the sensory factors. Furthermore, increasing the sample size with corrections with regard to the distribution of for example age, skill

### Table 6

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Canonical correlation</th>
<th>Mult.</th>
<th>df1</th>
<th>df2</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.91352</td>
<td>6.06</td>
<td>27</td>
<td>52.00</td>
<td>.000</td>
</tr>
<tr>
<td>2</td>
<td>.53033</td>
<td>1.37</td>
<td>16</td>
<td>102.00</td>
<td>.170</td>
</tr>
<tr>
<td>3</td>
<td>.24158</td>
<td>.67</td>
<td>7</td>
<td>52.00</td>
<td>.859</td>
</tr>
</tbody>
</table>

### Table 7

Correlations between the dependent (flow) and covariates (presence) and the canonical variables.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Canonical dimension 1</th>
<th>Standardized $r_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>Challenge/skill balance</td>
<td>-.44732</td>
</tr>
<tr>
<td></td>
<td>Clear goals</td>
<td>-.57274</td>
</tr>
<tr>
<td></td>
<td>Unambiguous and immediate feedback</td>
<td>-.70622</td>
</tr>
<tr>
<td></td>
<td>Merging of action and awareness</td>
<td>-.92771</td>
</tr>
<tr>
<td></td>
<td>Concentration on the task at hand</td>
<td>-.10894</td>
</tr>
<tr>
<td></td>
<td>Sense of control</td>
<td>-.95060</td>
</tr>
<tr>
<td></td>
<td>Altered time perception</td>
<td>-.33002</td>
</tr>
<tr>
<td></td>
<td>Loss of self-consciousness</td>
<td>-.10984</td>
</tr>
<tr>
<td></td>
<td>Autotelic experience</td>
<td>-.58284</td>
</tr>
<tr>
<td>Presence</td>
<td>Agency</td>
<td>-.92499</td>
</tr>
<tr>
<td></td>
<td>Learnability</td>
<td>-.42386</td>
</tr>
<tr>
<td></td>
<td>Interface quality</td>
<td>-.60221</td>
</tr>
</tbody>
</table>
level and musical background and further analysis of the dataset (e.g. investigate the relationship between presence and musical background or background in computer use, the role of skill or level of experience) are needed. Based on the results of the canonical correlation, it might be argued that a possible way to proceed could be to integrate both questionnaires (FSS and PSS) into one questionnaire.

3.3.2. Relationship of current findings on Presence to previous findings with the PQ

Despite the fact that a further elaboration and refinement of our presence questionnaire is required, the extraction of the three components related to agency, learnability and interface quality seems to resonate with previous research. First, the extraction of a component related to agency is in line with the theoretical elaboration of presence as a moment-by-moment self-monitoring process that informs a person whether actions are performed in accordance with his or her intentions and goals (Riva, 2008; Riva et al., 2009). In line with Witmer et al. (2005), this first component is a combination of previous revealed separate subscales (Witmer and Singer, 1998), namely involved/Control and Natural.

Second, the Learnability component relates to presence conceived of as a mechanism that informs about the relationship between goals and results. Learnability is acknowledged as important to the establishment of action perception couplings (see Zahorik and Jenison, 1998). It is also acknowledged as an important factor for the interaction with a computer system (Vertegaal et al., 1996).

Third, the component related to interface quality is a factor that has been found in previous research (Witmer et al., 2005; Witmer and Singer, 1998). However, in contrast to Witmer and Singer’s Interface Quality subscale, this component was not so much related to attention. Here items were rather about how the system responsiveness was experienced, how consistent or natural the system’s mappings were, and how much metal effort the system required.

Remarkably, four out of the five items that were excluded from the principle component analysis, namely attention to screen, attention to music, attention to mat, and attention to surroundings, were related to the original Sensory Factors (Witmer and Singer, 1998) and to the Sensor Fidelity Factor (Witmer et al., 2005). None of these items were significantly correlated with the PSS. This means that with regard to the questionnaire design, questions have to be revised to better capture the sensory aspect of presence. The fifth excluded factor, I succeeded to draw in different ways, was positively correlated with the PSS. This item might be related to the feeling of successfully enacting one’s intentions.

3.3.3. Flow and presence

Findings from this study seem to empirically validate the theoretically elaborated relationship between the constructs of flow and presence. Results from the statistical analysis suggest a strong relationship between both constructs and confirmed our hypothesis that presence has a predictive value for flow. These results are in line with previous findings on presence as a flow facilitator (e.g. Jacobson, 2001, 2002; Riva, 2009). Moreover, they can be related to the conceptions of presence as the “feeling of being there” (e.g. IJsselsteijn and Riva, 2003) and as the “perceptual illusion of non-mediation” (Lombard and Ditton, 1997). When action and awareness merge, a person is acting proximally (“here”) but thinking distally (“there”) (e.g. Loomis, 1992; Polanyi, 1966). Additionally, while being totally focused on the results of one’s actions, stimuli related to the actions needed to produce these results disappear from consciousness. This is only possible when the system responds well and using it feels natural. When this is the case, it invokes the so called “perceptual illusion of non-mediation”, i.e. when mediating artefacts of an activity disappear from consciousness and allow to completely focus on the task at hand (e.g. Nijs et al., 2009). This aspect is supported by the strong correlation that was found between the presence items non-mediation and system naturalness with the FSS. Furthermore, the system’s responsiveness and naturalness also enables its user to perceive oneself to be the agent in control (e.g. Mulder, 2000; Nosulenko et al., 2005).

The fact that the Learnability component had no significant predictive value for flow seems to confirm the findings of Turner (2008) who found in a study on familiarity with interactive devices that it is not the learnability with the technology per se that is the most important factor but rather the actual consequences and focus of the learning.

Remarkably, none of the three components of presence correlated with the flow dimension “focused on the task at hand”. In view of the generally acknowledged important role of attention processes in presence, this is a notable result. It might be explained by the explorative nature of the experiment: no concrete guidelines were given and participants had to concretize the task on their own initiative and inventiveness to make a digital painting. Many participants explored the possibilities of the system without defining for themselves a concrete drawing task (e.g. draw geometric figures or concrete objects such as for example a house or boat). Taken into account that most of the participants had no experience in improvising, this explorative behaviour is in line with the improvisation skills model as proposed by Kratus (1991). In this model, exploration is the first of seven levels that mark out a learning curve in the development of improvisation skills. Further experiments are needed to see the effect of very concrete tasks and how these affect attention processes when interacting with the Music Paint Machine. An aspect that did correlate with the flow dimension “focused on the task at hand” was the fact whether one’s was paying attention to the screen or not. This finding seems logical, considering the fact that the task involved to create something “on the screen”.

The findings above suggest the importance of the so-called illusion of non-mediation for flow. In the literature on flow, this aspect seems underrepresented. And yet this perceived non-mediation – and accordingly the degree to which the system is experienced as an extension of the body (Nijs et al., 2009, in press) – is very important for the possibility to focus on the task (Loomis, 1992; Polanyi, 1967; Finneran and Zhang, 2003). Therefore we believe that the construct of flow can be elaborated upon in depth by integrating the construct of presence. Further research is needed to empirically investigate the role of the different layers of presence (Riva et al., 2004a,b).
3.3.4. Presence and flow in the context of interactive music systems: the case of the Music Paint Machine

In this study, first steps were undertaken to introduce the measurement of presence in the domain of interactive music systems and related research. Based on a theoretical investigation of the musician–instrument relationship (Nijs et al., 2009, in press), it was found that presence is a viable construct in order to elaborate on the interactive processes during music performance. Therefore it was assumed that measuring presence is an appropriate method to, first, examine whether and, if so, to what extent the Music Paint Machine creates a meaningful environment for the musician and, second, to probe the possible immersion in this environment. This information is vital for the development of the system into an optimal learning tool. Especially when presence is closely related to flow. After all, the goal of the Music Paint Machine is to provide musicians with a flow-like experience in order to stimulate creativity, enhance the relationship with the instrument and develop an embodied understanding of the music.

The presented results suggest such a close relationship between flow and presence.

This implies that soft- and hardware adaptations that optimize the system in function of presence, will also positively affect its flow potential. According to Riva et al. (2004a,b), the technical demands of eliciting presence are less the higher the layer invoked. But designing a system that has the potential to elicit an optimal presence experience needs to enable the integration of the three layers of presence. The authors argue in favour of three design routes that can stimulate the sense of presence. The first route, digital participation, refers to the emotional and intellectual engagement. In the domain of virtual reality this means that the user of the system is the agent in an interactive drama. The second route, mediated flow, is related to perceived control and focus on the interaction, to the arousal of curiosity and to interest in the interaction. The third route, embodied immersion, is related to the style of the interaction, namely to the integration of bodily movements as direct inputs from the user. We believe that these three design routes are applicable within the domain of interactive music systems. These systems, especially when movement based, are capable of evoking digital participation, mediated flow and embodied immersion. Measuring the sense of presence when engaging with such systems might therefore capture essential aspects of the interaction, related to the role of the body as the natural mediator of human experience.

3.3.5. Presence, flow and embodiment

The empirically observed correlation between flow and presence can be understood from the viewpoint of embodied music cognition. We believe that embodiment is an interesting concept for understanding the mechanism that may connect the concepts of flow and presence. We argue that this underlying mechanism is the action-perception principle. Results of the empirical study seem to support this line of thought.

From the viewpoint of embodiment, the body mediates human experience by establishing a link between the environment and the experience. This link is based on the coupling of action and perception, which constitutes the mutuality between subject and environment. In this way action perception couplings provide access to the environment (perception) and enable a corporeal attunement with the environment that facilitates an embodied interaction (action).

It can be argued that the coupling between action and perception is a mechanism that underlies the intrinsic relationship between flow and presence.

First, the coupling of action and perception is crucial for determining the extent to which a subject has access to the environment and actions are successfully supported by it (Zahorik and Jensen, 1998). As such, this mechanism is a common ground for both conceptualizations of the quality of human experience. It underlies different flow dimensions such as the balance between skills and challenge, immediate feedback, sense of control and merging of action and awareness. It also underlies presence as the monitoring mechanism that informs a subject on the possible successful enactment of his intentions. This is reflected in the extraction of a presence component related to agency.

Second, the coupling of action and perception is the mechanism that allows for a presence-based elaboration of the role of the body and, particularly, its extensions for flow. If flow, as the results of our study suggest, involves optimal presence, then it is only possible when proto presence is achieved. Proto presence only occurs when it is possible to correctly couple perceptions and movements (action) and to use the body to successfully enact intentions. This implies that the “correct” coupling of action and perception is characteristic for an optimal sense of presence and vital for flow. In other words, it is through the action perception couplings that the body mediates experiences and its perceived quality.

Accordingly, when engaging with an interactive music system such as the Music Paint Machine, the quality of the musician’s experience is determined by the quality of the bodily engagement as reflected in the degree to which action and perception match. Therefore the system must be designed in such a way that the material components (e.g. motion sensor, pressure sensing mat, screen) and the actions that are required to use the system do not hinder a direct and engaged – bodily – participation (embodied interaction) in the environment that is created by using the system. The musician must be able to act in accordance with his skills (skill-based playing). Here the degree to which the musician feels in control, the naturalness of using the system, the degree to which unusual action are required and the degree to which system mechanism capture attention are important elements that influence the musicians interaction with the system. When these elements are favourable, the musician will feel competent in using the system. Additionally, the system must be designed in such a way that it does not hinder perception. The musician must be able to effortlessly pick-up the necessary information (direct perception) to evaluate a possible match between intended and actual results (e.g. what happens on the screen). Here the nature of the mapping and the degree to which the system allows to anticipate the results of an action are of importance.

When a system allows skill-based playing (e.g. painting with sound and movement) and direct perception (e.g. what happens on the screen), it does not interfere with the mediating role of the body for the musician’s experience. The system can become transparent in use and can be experienced as a natural extension of the musician that, unified with the body, mediates the access to the created environment.

The importance of the action perception coupling principle – and thus the role of the body and its extensions – for the aforementioned characteristics of the system and their impact on the musician’s experience are reflected in the clustering of the items relating to these characteristics into the agency and interface quality components. Through the clustering of these components with the flow dimensions related to control (sense of control) and to the immersion in the activity (merging of action and awareness), results of the empirical study with the Music Paint Machine shed light on how measuring presence might reveal the role of the body for flow.

4. Conclusion

In this paper we presented an approach to the measurement of the subjective experience of musicians engaging with an interactive music system, the Music Paint Machine. This system allows a musician to create a digital painting by playing an acoustical
music instrument and moving on a pressure sensing mat. The design of this interactive system is embedded in an embodied cognition approach to musical experience, in which interactive music systems are conceived as extensions of the human body. As such they have a major impact on the role of the body as the natural mediator of human experience.

To examine the nature of an experience with the Music Paint Machine, we used the constructs of flow and presence. Flow experience was measured with the Flow State Scale, presence with an in-house designed questionnaire. Based on theoretical accounts of the relationship between both constructs, we hypothesized that presence has a predictive value for presence. Statistical analysis confirmed this hypothesis. Furthermore, findings suggest that the intrinsic relationship between flow and presence is related to agency or control, interface quality and the merging of action and awareness.

Despite the explorative nature of the experiment and, consequently, the preliminary nature of the findings, results seem to resonate theoretical elaborations. However, findings also pointed to the need to further elaborate and refine the in-house designed questionnaire, especially with regard to the sensory aspects of presence. Further experiments are needed to test the reliability and validity of a next version of the questionnaire. A possible way to proceed might be to integrate flow and presence into one questionnaire. Furthermore the methodology of the experiments must be elaborated. Especially different tasks and variations of the system can be used to conduct more controlled experiments.

We believe for several reasons that music provides an excellent research domain in which presence can be studied. First, interactive music systems become more and more important in the cultural creative sector (e.g. music performance, education). The development and implementation of these systems demand for a user-oriented approach that has a strong theoretical ground. This ground can be provided by elaborating on flow and presence within the embodied music cognition paradigm.

Second, interactive music systems are often movement based. Using the construct of flow and presence in empirical studies with these systems might therefore reveal interesting aspects on the role of the body for the quality of subjective experience while engaging with such a system. Again, presence research and the embodied music cognition research paradigm might join and establish a firm empirical framework.

Third, bringing the construct of presence in the domain of interactive music systems might broaden the use of presence towards research on artistic expression and creativity. Finally, interactive music systems often use sensing technologies that provide objective data on, for example, movement and sound. This enables the combination of objective and subjective measurement of presence. Moreover, these systems are always multimodal. Therefore experiments with such systems can contribute to research on cross-modality and how the precise coupling of different modalities affects presence.

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