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Observing and Measuring the Flow Emotional State in Children Interacting with the MIROR Platform

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ABSTRACT

This paper introduces a study aiming to measure the Flow state (Csikszentmihalyi 1996) of children playing with the MIROR-Improvisation prototype, an Interactive Reflexive Musical System (IRMS) implemented in the framework of the EU-ICT Project MIROR-Music Interaction Relaying On Reflexion. The IRMS have been defined as Flow machine, thanks to their ability to imitate the style of the human playing a keyboard (Pachet 2006). The Flow grid was created with the software Observer (Noldus©). The basic idea of this grid is that the observer did not register the flow state but rather the "variables" and the "intensity" of each variable. The presence of Flow state is instead measured by means an automatic process of the Observer based on several constraints: according to Csikszentmihalyi, when the level of all variables is higher, the presence of Flow is indicated. 24 children (4 and 8 years old) carried out 3 sessions playing a keyboard in 3 consecutive days. In every session, all children played the keyboard with and without the MIROR-Impro, alone and with a friend. One group of children played the system with set-up Same and another group with set-up Very different (with set-up Same the system's reply is more similar to the child's input). The video collected were analysed with the Flow grid. The results show that the Flow state is higher when the children play with MIROR-Impro, with set-up Same and with 8 years old children. The difference between sessions is not significant. These results would support the hypothesis that the IRMS and the reflexive interaction can generate an experience of well-being and creativity. The Flow grid worked in effective way and it was possible to indicate some aspects of the system to be improved. Some limitations have been discussed for further adjustments of the grid.

I. INTRODUCTION

This paper introduces a grid measuring the Flow experience of children interacting with MIROR-Impro, one of the three software components of the MIROR platform, an innovative adaptive platform for childhood music education based on the *reflexive interaction paradigm* (Pachet 2006, Addessi & Volpe 2011). The IRMS have been defined as Flow machine, thanks to their ability to imitate the style of the human playing a keyboard (Pachet 2004, 2006). The Flow theory (Csikszentmihalyi 1996) had some influence on the studies on creativity in music (Byrne et Al. 2003; McDonald et Al. 2006; O'Neill and McPherson 2002; Sheridan and Byrne 2002; Custodero 2005, Addessi et al 2006, Smolej & Avsec 2007) and it is also considered one of the theories that best allows to grasp the important aspects of human-machine interaction (Leman et al. 2010). The concept of Flow machine integrates, in a very interesting technological hypothesis, the theories of creativity with the issue of human-machine interaction. It is therefore important to develop efficient tools to observe and quantify this particular kind of creative experience.

The study presented in this paper has two objectives: on the one hand it aims to verify the hypothesis that the IRMS (in this case the MIROR-Impro prototype) and the reflexive interaction enhance Flow emotional state in children and on the other side, it aims to create and test a tool to analyse the Flow state of children interacting with a Flow machine. This study grounds its origin in a previous study carried out with children interacting with the Continuator, the first prototype of IRMS (Addessi and Pachet 2005, Addessi et al. 2006).

In this paper, it will be firstly introduced the MIROR platform and the reflexive interaction paradigm, the theory of Flow and the studies on Flow and music. Then,the Flow grid and the experimental design carried out with children interacting with the MIROR-Impro prototype will be introduced. The results will be finally presented and discussed.

The research is carried out in the framework of the EU-ICT Project MIROR (Musical Interaction Relying On Reflexion).

II. BACKGROUND

A. The MIROR platform and the reflexive interaction

The MIROR Platform is an adaptive platform for childhood music education composed by three components: MIROR-Improvisation, MIROR-Composition and MIROR-Body Gesture. Each component aims to exploit the paradigm of "reflexive interaction" in the field of technology-enhanced learning. The "reflexive interaction" paradigm is based on the idea of letting users manipulate virtual copies of themselves, through specifically designed machine-learning software referred to as interactive reflexive musical systems (IRMS). The IRMS were firstly developed at the CSL-SONY in Paris (Pachet 2003, 2006). The idea was to develop a machine that gives to the user the perception to interact with something same as himself. In this case the machine does not exactly mimic the user's proposal, but own musical style, or, in other words own musical identity. The experiments that followed immediately after with adults (e.g. see Pachet, 2006) and especially with children (e.g. see Addessi & Pachet, 2005, Ferrari et al., in print) have made immediately obvious the potential of these reflexive systems for the development of creative musical experiences. The paradigm of reflexive interaction could contribute to the field of theoretical studies on music creativity, bringing a fresh perspective in technological and pedagogical applications. One innovative feature of the IRMS is the creation of a natural, organic dialogue with the child. This dialogue is based on the mechanism of *repetition and variation*, that is also a natural mechanism observed in infant/mother interactions (Papoušek 1995, Trevarthen 2000, Dissanayake 2000, Malloch 2000, Stern 2004, Imberty 2005, Gratier & Apter-Danon, 2008). The mechanism of repetition/variation is, in fact, at the heart of the reflexive interaction: the system's repetition of the input given by the child allows the child to perceive the response of the system as a sort of sound image of her/himself. And this is the moment in which the child shows an absolute attraction for this other that is similar to her/himself. The interesting thing is that it is not a merely repetition/imitation/echo, but rather a repetition always constantly varied. Now, it is exactly the co-presence of something that is repeated along with something different that seems to make the reflexive interaction a sort of device of attraction first, and then of stimulation of interest to get involved in the interaction."He repeats but it is different" in this sentence that a child of 5 years expressed after hearing for the first time the response of Continuator, seems to be contained the attractive power of the reflexive interaction. In Addessi & Pachet (2005), it is showed some examples of micro-analysis in which it appears this mechanism and how it develops:

1) Example 1: “After some minutes, Jerry (5 year-old) plays one note at random (G, staccato) and is about to fold his arms and listen to the machine’s reply, but the Continuator plays back the same note and merely adds the octave (G3-G4). Jerry recognises his own note like in a mirror: he is surprised, looks at the keyboard, lifts his hand and then immediately replies with the same note and a variation (G-G-A-A-B-cluster). This marks the start of a real dialogue based on repetition and variation: Jerry and the system reply to each other and add variations in register, rhythm, modes of playing (e.g. Jerry plays G staccato, Continuator: G-G staccato; Jerry: G-G-A-A-B-cluster, Continuator: cluster/rising arpeggio; Jerry: short cluster, Continuator: cluster, rising 3rd etc.). This type of interaction gives us a good idea of how the system is able to imitate and vary the child’s proposals, and how this aroused in the child a sequence of emotions going from surprise and interest, to curiosity, which encouraged him to turn a random single note (G) into an alternating succession of variants of a rhythmic-melodic cell, making up an interesting, albeit brief musical dialogue.(...) when the system's replies became very varied and the mirror effects vanished, Jerry lost interest, the dialogue ceased, and he asked for the game to stop.” (p. 32)

In this example, it is possible to observe several interesting things that characterise the reflexive interaction:

- the attention of the child increases when the system imitates the child's input and decreases when the system's replies become more varied
- the dialogue that emerges between the child and the machine is not predetermined by the machine, nor realised by the only child, but it is co-constructed by the child along with the machine;
- the co-regulation (Fogel 2000) is based on a continuously repetition-variation mechanism between input and output data from the child and the system, where:
  the partners' are able to imitate each other
  the child recognise to be imitated
  the repetition of something is always accompanied by the introduction of continuous variations
- the interaction is based on turn-taking: the child plays, then stops, waiting for the response of the system and when it comes s/he listens to it carefully, perceives its reflexive qualities and in turn the child responds by imitating and varying the system response;
- the response of the system takes as the last input played by the child: a kind of what psychologists call the *regular timing of turn*;
- notably in the second example, we observe a transition from *turn-taking*, the alternation between two interlocutors, to *role-taking*, i.e. the moment when one of the two interlocutors take the partner into account and as a consequence regulate your own behaviour according to that of the other;
- this type of interaction seems very close to that occurring in infant/adult interaction: in the exchange and vocal games of the child with the mother, the maternal voice acts as a sound mirror that reflects the vocal experience of the child and reinforce them.

Starting from the observation of children interacting with an IRMS, several theories have been considered to explain human behaviours in action during the interaction with a reflexive system. From a systematic perspective, the theoretical framework of the reflexive interaction paradigm could include references from the myth of Eco (Ovidio) to the more recent semiological paradigmatic analysis (Ruwet 1966; Nattiez 1986) and the theory of similarity perception in listening music (I. Deliège 2003; Toiviainen 2007). However, thanks to its capacities to replicate the musical behaviour and to evolve in an organic fashion with the user, IRMS translate into technological design several theoretical concepts of learning development and the theory of creativity. The capacity to replicate the behaviour of others grounds on one part on non-conscious processing known as the “chameleon effect” (Chartrand and Bargh, 1999). Recent studies (Lakin et Al, 2003) suggest that the mere perception of another's behaviour automatically increases the likelihood of engaging in that behaviour oneself. Neuroscientific studies root these non-conscious mechanisms in the mirror neuron system (MNS), a network of neurons, which becomes active during the execution and observation of actions (Rizzolatti et. al.1998, Rizzolatti et al. 2002).

The studies presented so far show the complexity of the processes put in place during a reflexive interaction, as that observed among children and the Continuator: *imitation*, *imitation recognition*, *self-imitation, repetition/variation* represent processes that develop in the first months of life and which structure the Self of the child and her/his interaction with the surrounding environment (Nadel & & Butterworth 1999). Another important aspect, that we can draw from this literature, is the importance given to the reflexive interaction as a *dynamic process*: the experience of repetition/variation is carried out inside of affective and emotional conditions, the *amodal* experience that Stern calls "affective contours", which are the contents of child's experiences of interaction with her/his mother.

B. Reflexive interaction and (music) pedagogy

It was proposed the reflexive interaction (RI) could ground a new model of (music) pedagogy in child/machine interaction (Addessi, in these Proceedings). The basic hypothesis of the MIROR Project is that the "reflexive interaction" enhances music learning and musical creativity in young children. Furthermore, we affirm that the IRMS can represent a new and original application of technology-enhanced learning. The pedagogical potential of the RI is based on the fact that the RI stimulates the subject to undertake a dialogue during which the repetitions/variations stimulate cognitive conflict that the child solves over the course of the interaction, giving rise to a learning by problem finding and problem solving. In previous studies with children, it was observed that the Continuator stimulated and reinforced conducts of an exploratory type, during which the child's actions were co-ordinate with the purpose of exploring the new partner, and which were characterized by the systematic introduction of new and different elements; but it also prompted inventive conducts, where the aim of the child's actions appeared to be to elaborate particular sounds and musical ideas and to undertake a dialogue with the system through the sounds. Both in the exploration and in the improvisations themselves, we saw very personalized styles in their approach to producing sounds, in their handling of the instrument and other equipment, and their working out plans of action to satisfy their own goals. The IRMS seem able to reinforce these individual styles, and allows them to develop and evolve. We have observed that the "teaching method" of the system is based on *turn-taking* and *regular timing turns*, on the strategies of *mirroring*, *modeling*, and *scaffolding*, and on starting up "affect attunement", *intrinsic motivation*, *collaborative interaction*, and *joint attention*. One of the most interesting aspects is that the invention is, in the end, not individual but collective: the child is playing along with the machine, in a pair, like two musicians improvising together. The way the children play also shows their stylistic competence, not only as listeners, as previous researches found, but rather as music-maker. We observed that RI increases the attention span, stimulates intrinsic motivation, musical creativity, attentive listening, collaborative playing and ability in collaborative improvisation. IRMS also exploit the Vygotskian concept of zone of proximal development (ZPD). In this way, IRMS establish an interaction between pairs, where the mirroring reflection creates a balance between challenges and skills, a basis to create Flow experiences and creative processes. This characteristic will enable the MIROR Platform to enhance self-regulation, self-initiated activities, and the learner-centred approach. Similar interactions based on the mirroring behaviour, have been observed recently in young children and adults while they play (Mazzoli 2003, Young 2004).

C. Reflexive interaction and creativity: the Flow Machine

As from Pachet (2004, 2006) the IRMS's ability to imitate the style of the human playing the keyboard, and its ability to maintain children's attention for long periods of time, has be interpreted through the theory of Flow introduced by psychologist Mihaly Csikszentmihalyi (1996). In short, the IRMS are also defined as Flow machine.

According to the theory of Csikszentmihalyi (1990, 1996, 1997, et al. 1988) the state of Flow can be defined as the psychological state of maximum optimism and satisfaction that a person perceives during the course of an activity and it is closely related to the concept creativity. The state of Flow is defined as "optimal experience" that results from the balance, perceived by the subject, between the challenge that you want to achieve and the personal skills to achieve or copy this goal. The Flow is characterized by the presence of high levels of a series of variables, which are: focused attention, clear-cut feedback, clear goals, pleasure, control of situation, awareness merged, no worry of failure, self-consciousness disappeared, the change of the perception of time. According to Csikszentmihalyi theory, in addition to the state of flow, other emotive states can be observed, defined as follows: arousal, control, boredom, relaxation, apathy. Also these emotive states are the result of different combinations of levels of the different variables.

Several studies applied the Flow theory in the field of music education, performance and composition (Byrne et Al. 2003; McDonald et Al. 2006; O'Neill and McPherson 2002; Sheridan and Byrne 2002; Smolej & Avsec 2007). Most of them are based on written interviews or questionnaires, as in Csikszentmihalyi's research method. Instead, Custodero (2005) introduced observational indicators of Flow state in young children daily musical experience. This study was important because it defined in detail a series of observable indicators of Flow to be grasped by the observer/teacher. Furthermore, it was developed in the particular field of infant musical experience thus providing scholars and teachers an useful tool for systematic Flow observation.

In the field of embodied cognition and human-computer interaction Leman et al. (2010) indicate the theory of *flow* as one of areas of expertise which should be explored to study the human/machine interaction. It discusses several tentative to measure the flow experience, based on questionnaire (Jackson and Eklund, 2004) and observational tools (Custodero 2005, Addessi et al. 2006). Also several objective measurement methods based on behavioural and psychological aspects of flow are discussed, related to facial expression, posture response, eye movement, heart rate, skin conductance (Laarni et al. 2004, Ivory & Magee 2009, in Leman et al. 2010).

D. Forward to the grid measuring Flow state

An observational grid measuring Csikszentmihalyi's variables and Custodero's indicators was proposed in Addessi et al. (2006). While in the Experience Sampling Method by Csikcszentmihalyi, the subjects tell about their own sensations, in our study the observer have to "read" the reaction of children during the games with the keyboard.

More in details, it was observed that children are engaged in focused activity both when playing and listening (focus attention); they play with the system in a self-motivated way, without any external constraints; the Continuator produces clear feedback and the interaction in some sense is reduced to the analysis of the feedback produced by the machine; the children were in control of the situation most of the time (c*ontrol of the situation*); the most striking result of the experiments (attention span, autotelic listening, Aha Effect) is related to the intrinsic motivation of the children. Excitement was clearly shown most of the time, in particular in the early phases of the sessions. As the results on attention span showed, for most of the children time passed very quickly. We also noticed the presence of the *flow indicators* by Custodero (2005):

- *Self-assignment***.** The activity is always initiated by the children (priority of the user).
- *Self-correction***.** During the interaction the children learn the implicit rules, assess her/his error and correct them (for example the turn-taking).
- *Deliberate gesture***.** The children' movements are very focused and controlled, both during the listening and the playing.
- *Anticipation***.** The interaction based on turn-taking and repetition/variation allows the children to anticipate something of the reply of the system, and to play on the base on this anticipation.
- *Expansion***.** As shown in the micro-analysis, the children progressively modified the material, reaching a good ability in organizing the time.
- *Extension***.** The children always continue to work with the material after the system (the "teacher" in Custodero's indicator) has finished.
- *Awareness of adults and peers***.** Both in the task alone and in pairs, we noticed that attempts to involve another person (and the system itself) physically or verbally are especially noteworthy.

We made a systematic observation of flow using an observation grid, and found that the percentage when the Flow state was present is higher in task B, with the Continuator (54%) than in task A, without the Continuator (42%) (for more details see Addessi *et al*., 2006).

Based on this study, it was decided to create a more robust grid to observe and measure the flow. This step allows to strengthen the previous qualitative observations by adopting a "mixed method" based on qualitative and quantitative analysis (Teddlie & Tashakkori, 2009). The mixed method, in fact, can simultaneously address a range of confirmatory and exploratory questions with both the qualitative and the quantitative approaches. It also aimed to create a tool at the same time more precise and more flexible that would allow, not only to observe the Flow, but also to correlate in a controlled manner the experience of the Flow to other different variables, such as: the use of the system, the kind of system response, the different set-up of the system, children's age, gender, if they play alone or with others, and so on. In fact, one of the aims of the Flow quantitative analysis was to observe and underline differences and/or correlations among dependent/independent variables and relative statistical significance. This procedure finally, should allow to identify in a more sophisticated way, any problems occurred in the child/machine interaction, giving out usability and user requirements (Leman et al. 2010).

III. MEASURING FLOW

A grid for observing and measuring the Flow state of children playing with MIROR-Improvisation was created with the Observer software (© Noldus). The basic idea of this grid was that the observer did not observe/register directly the Flow state, but rather the "variables" and the intensity of each variable. The presence of Flow state was instead measured by means an automatic process of the Observer based on several constraints given to the software (Data Profile tool). The grid codes the following variables indicated by Csikszentmihalyi, here defined as "behaviours" (Figure 1):

- focused attention
- clear-cut feedback
- clear goals
- control of situation
- pleasure

Figure 1. Flow grid: Coding scheme - Behaviours (Observer XT 10.5-Noldus).

For each behaviour it was decided to register the *value*, that is the *level of intensity,* by using the "Modifiers" tool (Figure 2):

1 = low level of intensity. The child shows one or more examples of behaviour that characterize the behaviour but in a not intense and in a piecemeal way, without continuing of that behaviour on a continuous basis.

2 = medium level of intensity. The child shows one or more examples of behaviour with an mean intensity and frequency.

3 = high level of intensity. The child shows one or more examples of behaviour in a very clear, intense and persistent way over time. In some cases the behaviour may be very short but it may have a high intensity and directionality of the gesture and gaze.

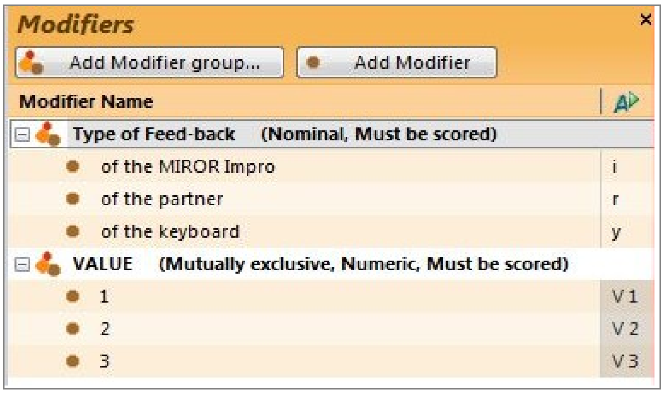

Figure 2: Flow grid: Coding scheme-Modifiers (Observer XT 10.5-Noldus).

The grid allows to record over the time:

- the *presence* of the behaviour
- the *frequency* of the behaviour
- the *duration* of each behaviour
- the *value*, that is the level of intensity of each behaviour

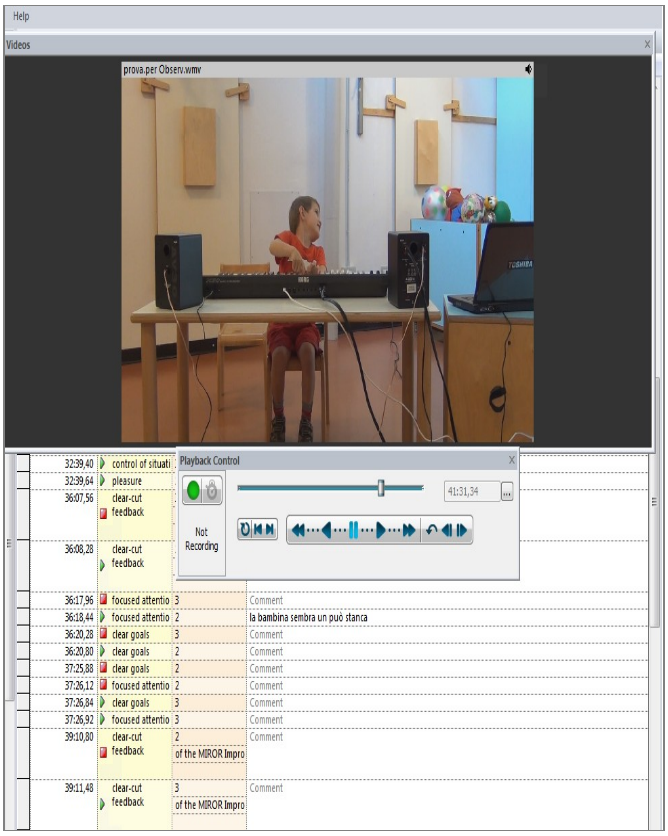

Figure 3. Flow grid: windows for registration of the observation (Observer XT 10.5-Noldus).

The Observer software calculates combinations of the different levels of the behaviours, on the basis of several constraints given by the researcher by means the Data Profile tool. It was possible to extract the Flow by means a particular data profile: the data profile was based essentially on a series of consecutive "nests" over the behaviours. The nesting allows to select among the data registered by the observers the combined presence of pre-defined level of the behaviours. In the Flow grid, according to Csikszentmihalyi, when the levels of all behaviours was recorded with high levels (modifier = 3) the state of Flow was indicated as present (Figure 4). To calculate the presence of the Flow, we decided to not insert the behaviour "pleasure" in the nesting of the data profile, according to the definition of Csikszentmihaly who refers to the pleasure as a result of the state of flow, that the subject perceives when he/she rethinks to his/her own experience of flow. Other combinations of levels of behaviours determine the state of apathy, boredom and anxiety.

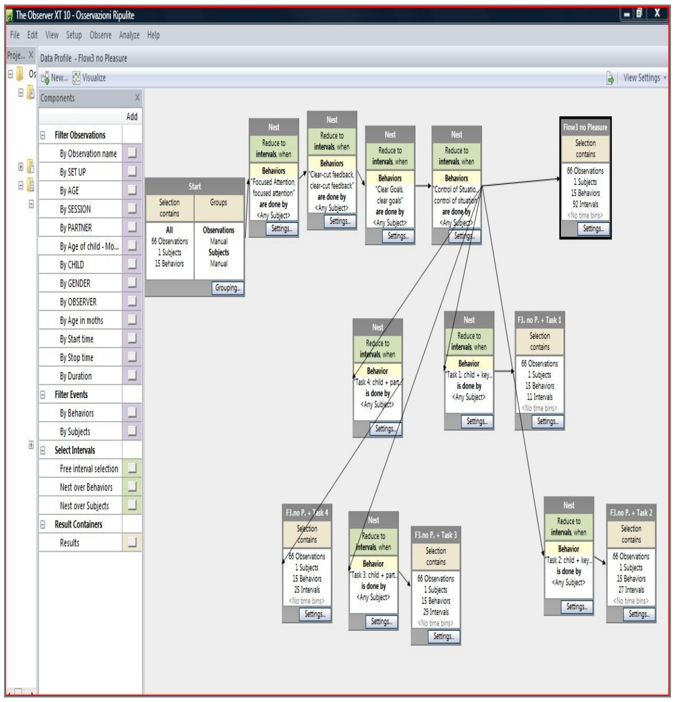

Figure 4: Data profile of Flow. It was obtained by an automatic process of Observer, by selecting only the high levels (modifier=3) of each behaviour registered.

E. Definition of the behaviours

The "Instructions for the observers", have been created and distributed within the observers. The Instructions included the description of each behaviour and the "practical actions" to register the behaviour using the software.

2) Focus Attention

The "focused attention" is an analytic behaviour of great intensity, is present when the child focuses on one or more particular elements. The focused attention is characterized by selective attention of the child. The child is not distracted by the environment, the teachers, the school noises, etc.. or other objects and people. Often this behaviour is accompanied by the direction and fixed gaze of the child on an object or a gesture. Some examples of behaviour that characterize the "focused attention": the child looks carefully the keyboard and/or other elements of the equipment (loudspeakers, monitors, cables, etc.); the child observes, he/she is careful and systematically explores some parts of the keyboard or other equipment; the child systematically explores some gestures of sound production...; the child is focused on particular musical idea, he/she plays a particular rhythm pattern on the keyboard, listens carefully to the response of the system, when the system stops, the child responds, in turn, continuing to repeat and/or elaborate the rhythmic patterns; the child listens attentively to own production, to the system responses, and the production of the partner.

3) Clear-cut feedback

The "clear-cut feedback" is defined by Csikszentmihalyi as "internalizing the field's criteria of judgement to the extent that individuals can give feedback to themselves, without having to wait to hear from experts"(1996, p. 114). In our case, the system continuously produces a clear-cut feedback and the interaction child/ system coincides with the analysis that the child realizes of the feedback received by the system. In our observations we will also determine how the child analyses/feels the feedback received from the partner (in the task in pairs) and from the keyboard when he/she is playing. Some examples of clear-cut feedback: the child becomes aware of the system's response and he/she reacts: smiling or saying something...; the child changes its musical proposal/response according to the response received from the system...; the child listens carefully to the response of the system, he/she reacts to the responses showing expressions of puzzlement, joy, surprise, or he/she watches the partner...; the child learns the rules of the system and learns to judge whether the response of the system will respect these rules...; “Self-correction" (Custodero, 2005): for example, the child attempts to imitate more the system.

4) Clear goals

The "clear goals" are present in situations where “the creative process begins with the goal of solving a problem that is given to a person by someone else or is suggested by the state of the art in the domain (…). In flow we know always what it has to be done” (Csikzsenmihalyi, 1996, p.113). During the interaction with the system, there are no set goals: children spontaneously create goals during the interaction. The goals are clear when the child's behaviours are intentional and not accidental. When the aims are clear, the children show the intention to find and to try spontaneously strategies, ways to explore and play the keyboard. These behaviours are acted out in a systematic way (repeating the gesture or sequence of gestures) and precise way (trial and error). Examples of behaviour that characterize the "clear goals”: the child shows to have the aim of exploring the parts of the keyboard and the elements of the equipment (loudspeakers, monitor, cables, etc..)..; the child shows to have the aim of exploring the different gestures to produce sounds: beats the keys with one finger, with an open hand, with elbow, arm, head, producing glissando, etc.; the child shows to have the aim of exploring the "sounds" of the keyboard and/or developing a musical idea: for example, the child plays systematically all white keys listening carefully, or all keys on the low register...; the child shows to have the goal of teaching to the system a particular musical patterns, such as a rhythmic pattern, or a "way" of playing...; the child has the goal of discovering the rules of interaction with the system and to invent new ones...; the child has the aim to interact with the system through a sound dialogue...; the child has the objective of responding to the system in an appropriate way.

5) Control of situation

The “control of situation” is present, according to Csikszentmihalyi when "we are too involved to be concerned with failure, it as a feeling of total control" (Csikzsentmihalyi 1996, p.112). That is, the child constantly checks (monitors) own actions during the interaction with the system. Some problems in monitoring may occur when the child is unable to interpret/understand the response of the system. Examples of behaviour that characterize the "control of situation”: the child understands quickly that he/she can interrupt the system when he/she wants; “Self-assignment "(Custodero 2005): activities (exploration, invention of a musical idea, etc..) are started by the child; “Deliberate gesture” (Custodero 2005): movements are well controlled, both during the listening and playing; the child explores and uses spontaneously, independently and with agility the equipment (keyboard, keys, computers, cables, etc.); in the tasks with the system (task 2 and 4), the child knows and knows how to use/ manage the rules of the interaction with the system, for example the child respects the turn-taking, he/she stops the “play” when she/he wants, inventing new rules of interaction and playing, etc.; the child explores different sound possibilities, listens and responds to the system by proposing ideas and in some cases even defiantly, et; in the tasks with the partner (task 3 and 4), the child manages/organizes the interaction and the play with the partner.

6) Pleasure

Csikszentmihalyi writes that the "flow is an innately positive experience, it is known to produces intense feelings of enjoyment" (Cszisentmihaly et al. 1988, p. 35). . Pleasure can then be defined as a situation of well-being and joy. In our encoding, the behaviour “pleasure” also includes the state of excitement. Examples of behaviour that characterize the “pleasure”: the child smiles and/or laughs, he/she is calm; the child shows no displeasure; the child repeats an action that likes to do, for example: exploring a musical idea, playing and listening to the system, doing a particular gesture, playing sounds they make fun for him/her, alone or together with the partner, etc.; the child “produces” exclamations of pleasure for example: "it responds to me!" or "it is fantastic!". The child speaks with the partner and shares with him/her the joy and fun through words and gestures; in some cases, when the pleasure becomes more intense and visible, the states of excitement can be observer by an increase in the intensity of the movement of the whole body, increasing the intensity of the gesture on the keyboard, an increase in the volume of voice, etc.

IV. METHOD

The aim of the protocol was to observe if the Flow state of children interacting with MIROR-Impro is affected by:

- the reflexive interaction
- the age of children
- the exposure to the system
- the presence/absence of a friend if the child play alone or with a friend.

In order to observe if the reflexive interaction affect the flow state, 2 variables were selected:

- *the use of MIROR-Impro*. The children were invited to play the keyboard both with and without the system. It was hypothesised that when the child plays with the system the flow state increases.
- *the system set-up*: two set-ups of the system were used: Set-up "same": it is based on the imitation of the input phrase. The set-up "very different": the answer of the system presents minor similarities with the user's input. One group of children used set-up Same and an other group used set-up Very different. It was assumed that when the child plays with set-up Same the flow state increases.

F. Participants

Total children involved in the experiment *n = 48*
Total children observed *n = 24:*
4 years old: *n* = 12
8 years old: *n* = 12

Table 1. Experimental design: participants and independent variables

	4-years old	**8-years old**
	with/without system alone/with a friend	**with/without system alone/with a friend**
Set-up SAME	N = 6 (3 boys, 3 girls)	N = 6 (3 boys, 3 girls)
Set-up VERY different	N = 6 (4 boys, 2 girls)	N = 6 (3 boys, 3 girls)

G. Equipment

MIROR-Impro prototype v. 2.5; a music synthesizer KORG X50; a notebook TOSHIBA - Techra (Windows 7, 64 bits); 2 amplifiers M-AUDIO AV30; an USB cable for the connection between the synthesizer and the notebook; a video camera, SONY (recording in HD) that was visible to the child; a tripod for the video camera.

7) MIROR-Impro set-up

The following different set-up of the prototype were used:

- Set up A: SAME
- Set up B: VERY DIFFERENT

The other parameters were programmed as follows:

- Phrase threshold: 400 ms
- Max legato ratio 0.5
- Keep only last 10
- Transposition: true
- Cleaned memory at the beginning of each task

H. Procedure

A preliminary collective meeting was carried out with each group of children. Then each child carried out 3 sessions in three consecutive days. In every session the child was asked to play 4 games with the keyboard, as follows:

Table 2. The games/tasks for each session

Task 1 the child alone	**Task 2** the child alone with MIROR Impro.	**Task 3** with a friend	**Task 4** with a friend, with MIROR Impro.
you can play the keyboard as long as you want. When you are tired call me	*you can play the keyboard and the keyboard answers to you. You can play as long as you want. When you are tired, call me*	*you can play the keyboard as long as you want. When you are tired call me*	*you can play the keyboard and the keyboard answers to you. You can play as long as you want. When you are tired, call me*

In tasks 2 and 4 , the operator launched the MIROR-Impro. In the 1st session the child was free to choose the first game-task. The tasks order of the 2nd and 3rd sessions was instead decided by the researchers (random order).

All the sessions have been video-recorded. Before the beginning of the protocol we collected the permissions signed by parents.

Each child was invited by their teacher to draw a picture of the experience, the week after the third session. The profile of the children were completed by teachers during the third week of the protocol. The questionnaires for parents were distributed at the end of the protocol and collected by the teacher.

I. Experimental hypothesis

The basic hypothesis of MIROR project is that the reflexive interaction and the mechanism of repetition/variation implemented by the IRMS could enhance creativity and learning processes. Consequently the experimental hypothesis is that the Flow emotional state increases when children playing with the MIROR-Impro and with set-up Same. Furthermore, we want to observe if any correlation occurs with the flow and the other independent variables: age, alone/with a friend, exposure to the system (3 sessions).

J. Data analysis

The Flow grid, created with the software Observer (©Noldus), has been used for the registration of the observation. Five independent observers registered the observation of the behaviours and the modifiers. Reliability tests within the observers have been realised before to start the registration and during the registration of the observation. The cases of disagreement were solved by collective discussions and observations. The Observer software calculates combinations of the different levels of the behaviours. When the levels of all behaviours are recorded with high levels (modifier = 3) the Flow state is indicated as present. Further software were used for the statistical analysis. The tasks analysed are showed in Table 3.

Table 3. Tasks analysed

	Set-up A=SAME				Set-up B=VERY different			
	Without the system		With the system		Without the system		With the system	
	T1	T3	T2	T4	T1	T3	T2	T4
4 years old children	15	17	12	13	16	16	12	13
8 years old children	13	15	12	11	11	10	12	10
Total	28	30	24	24	27	26	24	23
Total tasks for set up	100				100			
Total tasks analysed	**200**							

V. RESULTS

K. Flow state in all subjects for each task

Figure 5 shows the percentage of Flow registered in each task, that is the total duration of flow compared with the total duration of the task. It shows that the percentage of Flow is higher when the child/children play with MIROR-Impro (Task 2 and Task 4). This result supports the experimental hypothesis that the Flow state increases when child/children play(s) with the MIROR-Impro prototype. However, this result does not mean yet that the higher flow is due to the reflexive interaction. In fact, it could be also supposed that the interaction with a system reply could create a flow state, independently of the quality of the system's reply.

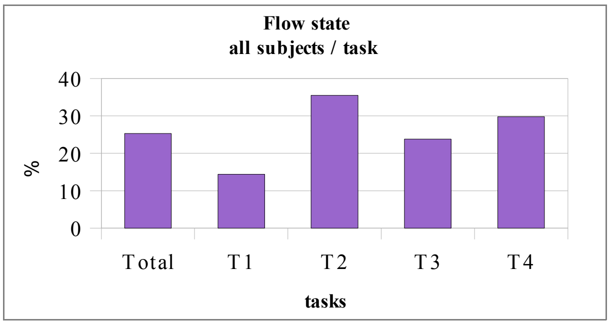

Figure 5: Percentage of Flow registered in each task in all subjects.

L. Do the set-ups Same and Very different affect the Flow state ?

Figure 6 shows the percentage of the flow in each task with set-up A=SAME and set-up B=VERY different (blue colon). The Flow percentage is higher with set-up A=SAME, that is when the system's reply is more similar to the input played by the children. The difference between set-up Same and set-up Very different is significant (p=.004). This result support the experimental hypothesis that the Flow state increases when the system's reply is more similar to the input played by the children, that is when the system's reply is more "reflexive". In this case it is therefore possible to say that the result support also the hypothesis that the reflexive interaction could enhance the flow state.

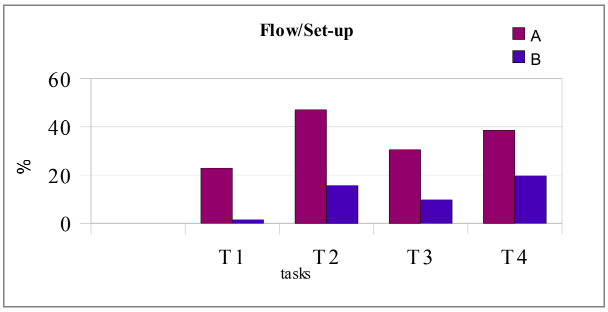

Figure 6: Flow percentage with set-up A=SAME and set-up B=VERY different in each task. ***Set up A*set up B: t Student= 8.151; degree of freedom: 3; p= .004.***

However, further consideration could be advanced about the set-up Same and Very different. In fact, the results of the experiment also showed that the *attention span*, that is the the duration of each task, decreases when the children play with the system (h:mm:ss: T1=06:27:52; T2=05:45:19; T3=08:40:37; T4=07:19:21),whereas in the pilot protocol with the Continuator, the attention span increased when children play with the system (Addessi & Pachet 2006). As the mean difference between the pilot study with the Continuator and the experiment with the MIROR Impro is the set-up SAME and VERY different, we should consider whether they could have negatively affected the children's attention span and in some way the flow experience as well. It seems that the particular combination used with SAME is not suitable for the cognitive process of musical memory with young children. In fact, in set-up SAME "the system starts the output with the input starting note, and produces a continuation from there (and) the system ends the melody with the input ending note" (User Manual MIROR-Impro v.2.5, p. 16). However, is the child able to "memorize" and "recognize" the first and the last note that he/she just played, considering the child played long phrase? In our opinion, he/she does not, for at least two reasons: the main reason is that only one note could be not enough to create a significant perceptual "cue" to be memorized and recognised after so long time, not only with young children but also in the adult (e.g. Deliège 2003). It means that memorizing the first and last note played is very difficult task for the children. It does not mean that the results do not confirm the hypothesis that MIROR-Impro generates flow state, but rather that further adjustments of the set-up should be introduced to improve the ability of the MIROR-Impro to act as a Flow machine. For example allowing the user to set-up by him/herself the degree of repetition/variation on the base of the user age and expertise.

M. Does the age of children affect the Flow state ?

Figure 7 shows the percentage of the flow in each task with 4 (blue column) and with 8 (green column) years old children group. The Flow percentage is higher with 8 years old children. The difference between 4 and 8 years old is significant (p=.001).

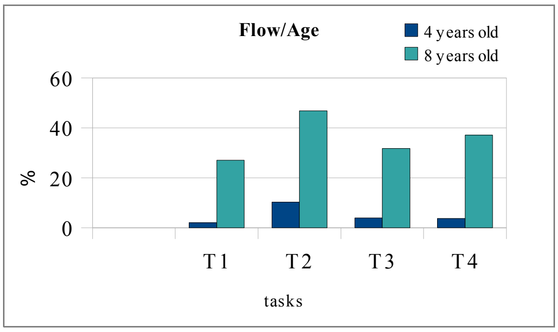

Figure 7: Percentage of flow in each task with 4 and 8 years old children in each task. *set up A*set up B: t Student= -11.676 ; degree of freedom 3; p= .001*

N. Does the exposure to the system affect the Flow state?

Figure 8 shows the Flow percentage in each task in session I, II and III. The difference between Session I and session II, session II and III, session I and III are not significant.

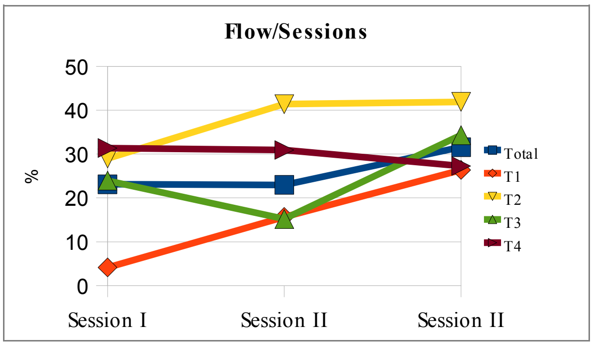

Figure 8: Flow Percentage in session I, II and III
*Session 1*session 2: t Student= -0.725; df = 3; p= .521*
*Session 2*session 3: t Student= -1.299; df = 3; p= .285*
*Session 1*session 3: t Student= -1.899; df = 3; p= .154*

These result show that the Flow state remains constant over the time, at least over 3 sessions in three consecutive days. However you can see that the percentage of the Flow in Task 1 (the child alone without the system, orange line) and in Task 2 (the child alone with the system, yellow line), increases over the three sessions; in Task 3 (with a friend and without the system, green line) it decreases in Session II and increases in Session III, whereas in the Task 4 (with a friend, with the system) the Flow decreases in both Session II and in Session III. It is therefore possible to observe that the flow state decreases when children play together. This is in line with the Flow theory (that describe the flow as a subjective state) and with the previous experimental result from the pilot protocol.

O. The "variables" or "behaviours"

As described above, the grid codes the following variables indicated by Csikszentmihalyi, here defined as "behaviours".

- focused attention
- clear-cut feedback
- clear goals
- control of situation
- pleasure

It is therefore possible to emerged the results related to each behaviour in each task:

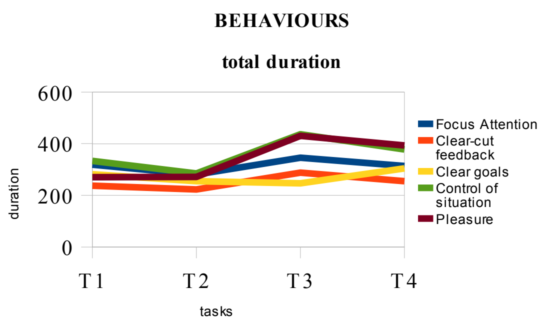

Figure 9. Trend of the behaviours: focused attention, clear-cut feedback, clear goals, control of situation, pleasure.

In Figure 9 it is possible to observe the duration of each behaviours in each task. It is possible to observe that focused attention, clear-cut feedback, control of situation and pleasure both decrease in task 2, increase in task 3 and decrease in task 4. The flow is higher in task 4 because the presence of these behaviors decreases in task 4 but it increases their level of intensity, which has generated the emergence of the state of flow. Furthermore, task 3 and 4 are higher than Task 1 and 2. This result seems to indicate that the presence of a friend increase these behaviours more than the presence of the system. Instead, the clear goals increases in Task 4: this result seems to indicate that when children play together and with the system they have more clear goals.

It is not possible to present in details the results concerning each behaviours. It is possible to synthesise the presence of some constants in all five behaviours:

- the percentage of each behaviour is higher with the set up "A"=SAME
- the percentage of each behaviour is higher with the 8 years old children

These two findings confirm the results enhanced with the Flow analysis. However, it is possible to observe some interesting data about the trend of each behaviour related to the age and the set-up:

- the trend of each behaviour is similar with the age: i.e. the trend of each behaviour with 8 years old and with 4 years old proceeds in parallel lines
- the trend of each behaviour is different with the set up. The trend with the set up B is generally more constant, instead the trend the of each behaviour with the set up A presents some peaks.

VI. DISCUSSION

As far as the reflexive interaction paradigm, the results suggest that the system MIROR-Impro and the reflexive interaction could enhance Flow state in children, funding the condition for creativity processes. The results show that the *Flow emotional state* increases not only when children play with MIROR-Impro, but also when they play with the set-up Same, that is the more “reflexive” set-up used in the experiment. Furthermore the Flow state is more evident when children play alone with the system. These results would support, by means quantitative data, a wide range of quantitative observations related to the mechanism of mirroring, repetition/variation, imitation, turn-taking, co-regulation, which characterize the reflexive interaction, showing that they could be able to create flow experience, well-being and creativity process. From a pedagogic point of view this aspect is of utmost importance since it stimulates learning and creativity, as well as encouraging an interest in musical instruments (Delalande 1993, Burnard 2006, O'Neill & McPherson 2002). We are now working to correlate these data with the analysis of musical improvisations generated by children during the sessions.

The results also show that the MIROR-Impro generates a higher level of Flow in the older children and several improvement should be discussed to better adapt the system to younger children. These data, however, could also point out two considerations: the first is that the flow of younger children could be different and expressed differently than older children. The second consideration is that the proposed Flow grid could be more suitable for observing the flow of older children. An adjustment of the grid for younger children should be foreseen by using the flow indicators by Custodero (2005).

Some results have also highlighted some issues not yet fully functional in the prototype that can be improved. In particular the reflexive qualities of set-ups Same and Very different can be enhanced and improved, taking into account for example the children auditory perception of similarity (e.g. Deliège 2003, Toiviainen 2007).

The grid as well as making it possible to support the hypothesis of Flow machine (Pachet 2004), lends itself to be used for other experiments in particular for measuring the state of creativity in child/machine interaction, that is very important in the field of technology-enhanced learning and human-machine interaction (Leman et al. 2010) and more in general in music education (Custodero 2005, McDonald R. et al. 2006). Furthermore, it may be also applied for user experience test of the other components of MIROR platform, in particular way of the MIROR-Body Gesture, devoted to empowering the reflexive systems by means the expressive gesture analysis (Camurri et al. 2009, Leman 2007, Volpe et al. 2012). In this case, it would be helpful to integrate the Flow grid with other dimensions and tools (e.g. Jackson and Eklund 2004, Lesaffre et. al. 2009, Leman et al. 2010).

The operational definition of behaviours must be reformulated on the specific situations in which the grid is applied. Nevertheless we believe that one of the main effort and result of the Flow grid introduced in this study was the operational definition of flow behaviours. In order to analyse more in detail if the reflexive behaviour of the system affects the children's flow state, further data analyses are currently being performed: by means an auditive analysis, different levels of repetition/variation of the system's reply will be grasped and then correlated with the flow results. For the future we plan to use the Flow grid to studying more in details the correlations between the flow experience and the children's musical improvisation, the children's listening conducts, and the role of the teacher.

VII. CONCLUSION

This paper introduced a study aiming to measuring the Flow experience of children playing with the MIROR-Impro, a particular system for childhood music education, based on the reflexive interaction paradigm, implemented in the framework of the MIROR Project. The results obtained with an original Flow grid, allow to confirm the hypothesis concerning the reflexive interaction enhancing flow experience and emerged several features to be considered for the improvement of the prototype.

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