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# Experiments with a musical machine: musical style replication in 3–5-year-old children

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*The relationship between new technology and learning is gaining increasing relevance in the field of music education (Webster, 2002; Folkestad* et al.*, 1998). However, only a few studies have considered the nature of the interaction between children and musical machines. This article describes an observation study of children aged 3–5 years confronting a particular interactive musical system, the Continuator, which is able to produce music in the same style as a human playing the keyboard (Pachet, 2003). The analysis of two case studies suggests that the Continuator is able to develop interesting child/machine interactions and creative musical processes in young children. It was possible to observe a 'life cycle' of interaction, as well as micro-processes similar to those observed in child/adult interactions (Stern, 1985; Imberty, 2002). The ability of the system to attract and hold the attention of children has been interpreted through the theory of flow introduced by Csikszentmihalyi (1990).*

## Introduction

The present study deals with an area still under-studied, that of interactive musical systems, and attempts to understand in what way these systems can affect the learning and musical creativity of children. In particular, we chose to study young children aged 3–5, because at this age the problem of the interaction between child and machine takes on a fundamental role in the learning process. According to some developmental theories (Fogel, 2000; Stern, 1985; Trevarthen, 2000), the infant/adult interaction plays an important role in the affective and cognitive development of the child. In particular, in the field of music development, Imberty (2002), in accordance with Stern (1985), describes the musical development of a young child as based on the vocal interaction with the mother, characterised by fluent mechanisms of repetition and variation and affect attunements. Recent studies dealing with musical invention in very young children (2–4 years) have suggested that the origin of new musical ideas is structurally anchored in the development of the sympathetic interaction established between the adult and child while playing with educational musical instruments (Young, 2004). Mazzoli (2003) refers to the Vygotskian concepts of modelling, scaffolding, and mirroring, and the relative mechanisms of interaction they involve, to provide an operative definition for the role played by the educator in musical games in the nursery school. The interesting question therefore arises as to which models of development and learning are produced when these relationships are established not between two human subjects, but between a child and a machine. An experimental protocol was therefore designed to observe young children playing with a musical machine.

This paper will present an overview of the literature on musical education and new technology, a description of the interactive system we used, the observation setting, and an analysis of two case studies. We will then draw some conclusions regarding the psychological and pedagogical implications of our study.

### Music education and new technology

The relationship between new technology and learning is gaining increasing relevance in the field of music education. The new technologies have been viewed by researchers as pedagogical tools (Webster, 2002), or as 'transparent' instruments that allow children, even outside the schoolroom, to make and produce music (Folkestad *et al*., 1998). Many studies have also documented the impact of new technologies on the music curriculum and its teaching methods (e.g. *British Journal of Music Education*, 14/2, 1997; *Les Dossiers de l'ingénierie educative*, 43, 2003).

This subject also has a more theoretical aspect, regarding the relationship between new technological language and the development of knowledge (De Kerckhove, 1993; Maragliano, 1999; Turkle, 1984). The questions most frequently asked are: What are the learning modalities determined by digital communication? What are the new 'cognitive frames' that new technologies are creating, in other words the context in which children develop the processes of music learning and perception?

Within the issues presented above is an area still rather under-studied, that of interactive musical systems. From this point of view, studies in the domain of artificial intelligence are producing interesting results (e.g. Camurri & Coglio, 1998; GRM, 2000; IRCAM-MusicLab, 2002). Only a few studies have observed the nature of the interaction between children and musical machines 'in the field', especially in the pre-school age range (e.g. Mazzoli, 2001).

### Interactive reflective musical system: the Continuator

In our study we used a particular system, the Continuator, developed at the Computer Science Laboratory, Sony, in Paris (Pachet, 2003), which was originally designed in the context of developing new tools for improvised music. This system is able to produce music in the same style as a human playing the keyboard, like a sort of sound mirror. An important consequence of this design is that the phrases generated by the Continuator are *similar but different from* those played by the users.

To illustrate the working of the Continuator, a simple musical example is given below (Fig. 1). The example is notated exactly as it is played, i.e. without rhythmic quantisation. This shows how the Continuator adapts quickly to arbitrary styles and is able to generate musical material that 'sounds like' the user input on a relatively small scale. In the standard mode, the system receives musical Midi input from one musician. The output of the system is itself sent to a Midi synthesiser and then to a sound reproduction system. The system is essentially a sequence continuator: the note stream of the musician is continuously segmented into musical phrases. Each phrase is sent asynchronously to a phrase analyser, which builds up a model of recurring patterns. In reaction to the played phrase, the system immediately generates a continuation, according to the database of patterns already learnt. Issues related to capturing higher-level structure are not discussed here as they are not relevant for our purpose (see Pachet, 2003 for more details). The Continuator keeps on


Fig. 1 A simple melody (top stave) is continued by the Continuator in the same style

learning from whatever input is given. As a consequence, the behaviour of the system improves over time.

The basic playing mode of the Continuator is a particular kind of turn-taking between the user and the system that is governed by three principles:

1. Automatic detection of phrase endings. The Continuator detects phrase endings by using a (dynamic) temporal threshold (typically about 400 milliseconds). When a time lapse exceeds this threshold, the Continuator takes the lead, and produces a musical phrase.
2. The duration of the phrase generated by the Continuator is parameterised, but in most cases the duration is set to be the same as the duration of the last input phrase.
3. Priority is given to the user. If the user decides to play a phrase while the Continuator is still playing, then the system will stop and return to listening mode (and eventually apply principle 1 again).

Experience with the system has shown that these rules are usually easily learned by the user in an implicit way – the behaviour of the system is usually obvious, even for children.

Many projects have been undertaken to propose ways of enabling young children to play music, with the goal of developing musical abilities early by designing musical instruments that are easier to play than conventional ones (IRCAM-usicLab, 2002; Weinberg, 1999), or by developing tools that allow children to become instrument designers themselves (Resnick *et al*., 1996). Many of the features we thought were exciting for professional musicians, such as the organic capacity of the system to learn musical styles and its ability to respond in real time, proved just as exciting for non-musicians and young children. In all cases, the main lesson learned from these experiments is that it is worthwhile to design and use a particular class of *interactive systems* – we call them *reflective* – for music education: systems in which the user, regardless of skills, competence level, and musical goals, is confronted by a developing 'mirror' of him- or herself. This unusual situation creates strong subjective feelings that we believe can be exploited for enhancing musical creativity and for teaching musical skills in general. The core concept of this approach is to teach powerful – but complex – musical processes indirectly by putting the user in a situation where these processes are developed not by the user, nor by the machine, but by the *interaction* between the two.

An experiment was conducted by the second author in Paris with eight children aged 3 and 4 years, who were invited to play a keyboard. When the children showed signs of boredom, the keyboard was connected to the Continuator. A certain number of interesting points were observed in this experience, relating to the power of attraction/addiction, the increase in time of attention, and the development of analytical behaviour (Pachet & Addessi, 2004).

## The study with children and the Continuator

An experimental protocol was subsequently established to observe systematically some interesting aspects of behaviour noted during the first experience, in relation both to the age of the children (3–5) and to the amount of exposure to the experience, and also taking into account whether the children were playing alone or together with another child. From a psychological and pedagogical point of view, the general aim was to study the nature of the interaction between the children and the system, the kinds of musical behaviours that developed, and how interactive systems can be used in the educational field to stimulate creativity and the pleasure of playing.

The observation was trialled in the nursery school 'La Mela' of Quarto Inferiore (Granarolo, Bologna, Italy), in collaboration with the Istituto Comprensivo of Granarolo. The collaborators consisted of a teacher from the school who is also a lecturer at the Faculty of Education, University of Bologna, two graduates in Education, the other teachers of the school and the children's parents.

### *Method*

#### Observation of video recordings and photos

Taking into account the age of the children (3–5 years), and wishing to provide a setting where the children felt at ease, we chose the observation method, which allowed us to observe the conducts of the children without disrupting their daily routine at the nursery. The term 'conduct' refers here to the French term 'conduite' as used and scientifically defined by Pierre Janet, Jean Claparède and Jean Piaget.[1] Controlled observation is possible, according to Piaget's 'quasi experimental' procedure, by means of continuous and systematic observation of the children's conducts in the field, taking into account various hypotheses and monitoring defined variables (Camaioni *et al*., 1988). In our experiment the variables were: the 'partners' with whom the children were invited to played (the keyboard alone, the Continuator, another child), the exposure to the experience (once daily for 3 consecutive days), and the age of the children (3–5 years).

#### Audio recordings

We also collected audio recordings of the improvisations played by the children and the Continuator, to aid the analysis of the musical 'process' (i.e. the transformations of the children's musical improvisations that took place during each successive session) and 'product' (i.e. the improvisations themselves) (Mialaret, 1997; Folkestad *et al.*, 1998).

#### Drawings

The children were asked to draw the experience one week after the video recording.

#### Questionnaire

The parents were asked to complete a questionnaire about the musical taste and experience of their children, and about their interaction with computer, TV and hi-fi.

#### Profile of the children

The teachers provided psychological and educational profiles of all the children involved.

#### Equipment

We used: the Continuator, a laptop computer, a Roland ED PC-180A keyboard as the interface, a Roland expander, a pair of amplified loudspeakers, a video camera, and a digital camera. The basic playing mode of the Continuator was the particular kind of turn-taking described above. The duration of the phrases played by the system was set to be the same as the duration of the last input phrase played by the child. These parameters were set without explicitly telling the users.

#### *Procedure*

The observation was preceded by a short meeting between the operators and the children. The meeting lasted about 20 minutes and was held in groups (two groups of approx. 15 children each). The aims of the meeting were to introduce the staff to the children, to get to know the children, and to prepare them for the experimental activities. During this meeting games were played, also involving the keyboard and the Continuator.

The video observation took place in the days following the meeting. Video and audio recordings were made in the small library of the school. The keyboard was placed on a table in front of the children and the portable computer on a nearby table. A video camera (not visible to the child) was positioned in front of him/her, in order to record both hands and face. One collaborator worked with the video camera, while another worked with the children and the computer. The sessions were individual (1 child) or in pairs (2 children). The children were supervised in the library by the operator or by the teacher. The operator gave the assignment to the child (if necessary he turned on the computer), and while the child was working, he either stayed in the same room and kept busy (reading, tidying), or left the room. The children were left increasingly on their own until the third session, when they were alone in the room. The children were asked to play in 4 different ways: with the keyboard alone, with the Continuator, with another child, and finally with both another child and the Continuator. The operator asked the child to perform the following 'musical games':

> The child alone:
> *Task 1*: 'Play the keyboard for as long as you like. When you are tired, call me'.
> *Task 2*: 'Play the keyboard for as long as you like and it will answer you. When you are tired, call me'. (For this task the operator activated the Continuator through the computer.)
> The child with another child:
> *Task 3*: 'Play the keyboard together for as long as you like. When you are tired, call me'.
> *Task 4*: 'Play the keyboard for as long as you like and it will answer you back. When you are tired, call me'. (For this task the operator activated the Continuator through the computer.)

The tasks were given in random order to make sure that the different tasks were not always performed in the same order. If the children asked to play with a friend or to start with one particular task they were allowed to do so. The list of tasks was in any case modified so that in the next session a child would not repeat the tasks in the same order. All sessions were recorded on video. The music played by the children and the systems was recorded by the same system. After one week the children were asked to draw a picture of the experience. At the same time, their parents were asked to complete a questionnaire. The teachers were asked for a profile of each child.

### *Participants*

The observation was carried out with 27 children (13 boys, 14 girls). Nine children performed all 4 tasks in all 3 sessions: 3 aged 3 years (1 girl, 2 boys), 3 aged 4 years (2 girls, 1 boy), and 3 aged 5 years (1 girl, 2 boys). The other children only took part in the tasks in pairs, or in free sessions, which were also recorded on video. The children all participated on a voluntary basis and were from two different school classes. Care was taken not to diverge from their normal daily routines. The job of the operator was to check that the children completed the protocol, with the tasks in random order. This fluid organisation of the protocol made it possible to fit the experiment into their normal school routine in a natural way, allowing us to observe them under everyday conditions and encouraging the children to express themselves in a relaxed and spontaneous fashion. This was made easier by the organisation at La Mela school, which was based on modules and open class projects, offering the children a high level of autonomy.

### *Data analysis*

The data collected were wide-ranging and interesting, and stimulated us to go more deeply into certain aspects, some of which had not been foreseen in the original protocol.

The video recordings were analysed as follows. First of all, they were watched by two independent observers who extracted the most significant parts and divided them into thematic areas: 'Interaction with the system', 'Listening and aesthetic experience', 'Ways of playing', 'Exploring the instrument', 'Joint attention', 'Musical improvisations'. This step


(a)

Fig. 2a Narrator, player, listener

was taken in order to give us an overall idea of the material we had gathered and to highlight any aspects not foreseen in the original objectives. The videos were edited to enable us to study side by side the 9 children who had completed the whole protocol. After watching the videos, and referring to the notes taken while making them, two case studies were selected for their interesting and contrasting characteristics. They were both boys of the same age: the marked contrast in certain of their conducts led us, in fact, to rethink our conclusions about the variables sex and age. The analysis focused in particular on the nature of the interaction between child and system, and on the evolution of this interaction during the course of the three sessions. A descriptive analysis was made to help us select some of the most significant moments, varying in duration from around 20 seconds to 2 minutes, which were then subjected to a micro-analysis; this also enabled us to build a dynamic profile of the evolution of the interaction. The duration of each task was measured to assess the attention span in relation to the different partners the child had played with.

A descriptive analysis was then made of the 7 other children who had completed the whole protocol. The attention span of the children was measured for each task. The most interesting data observed in the two case studies were compared with the other children by means of an observation grid. In this paper we report some examples of the thematic areas that emerged, together with the results of the analysis of the two case studies.

### *Results: general aspects*

#### Interaction with the system

The most common types of interaction identified were sensory-motor (touching and handling), symbolic (e.g. dramatisations, 'let's pretend') and rule-based. The children danced, sang, listened, went through different emotional tones, and often expressed aesthetic opinions. They tried to understand the rules of the system. They listened carefully in order to create 'musical' dialogues with the system. They sometimes even narrated a story while listening to the Continuator (Fig. 2a).


(b) (c)

Fig. 2b They listen to the keyboard as it answers, and share their perplexity. Fig. 2c Joint attention – ‘Aspetta’: one girl stops her friend in order to listen to the machine

### Relationship between pairs of children and the system

Of particular interest are the relationships established between the two children when playing together, and between them and the system: playing, listening, exploring together, watching the partner’s reactions, playing separately, alternating, or conflicting (Fig. 2b). A typical situation encountered was the phenomenon of ‘joint attention’: more precisely, one of the children would force the other to stop playing in order to listen to the situation. We call this situation ‘Aspetta’ (the Italian word for ‘wait’) (Fig. 2c).

### Listening and aesthetic experience

The listening was very careful, both to the replies given by the system and to their own work. Sometimes the listening gave rise to moments of sheer ecstasy, sudden outbursts of joy, and excitement (Figs. 2d and 2e). Another child, Alberto, listened to the system and exclaimed: ‘E bellissimo!’ (‘It’s wonderful!’).

### Ways of playing; exploring the instrument

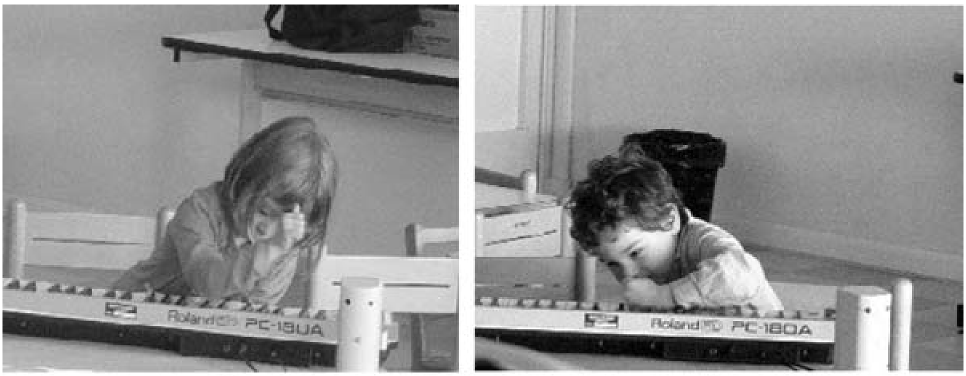
The children explored the keyboard and means of making sound in a myriad different ways: with their elbows, heads, bottoms or forearms, with their hands in their sleeves, chopping, with just one finger, several fingers, the palm of the hand, facing backwards, rubbing, alternating the hands/fingers (Figs. 2f and 2g).

### Musical improvisations

A preliminary analysis of the improvisations revealed rhythmic and melodic patterns, synchronisation on the same pulse, forms of song and accompaniment, individual

(d) (e)

Fig. 2d Listening and ecstasy; Fig. 2e Listening to the Continuator




(f) (g)

Fig. 2f Exploring the machine with her elbow. . .; Fig. 2g . . . and with his fist

improvisation styles, brief formal constructions based on imitation, repetition, alternance and contrast.

### Two case studies: the 'life cycle' of interaction

The first phase of observation allowed us to observe an initial dynamic curve that moves from *Surprise* (the *Aha effect*) to a phase of *Excitement*, followed by a period of *Concentration and analytical behaviour*: we called it the 'life cycle' of interaction. In the two case studies we concentrated on the quality of the analytical behaviours and the ways in which the child/computer interaction starts, develops, and ends. We will present the *attention span* (the time of every 'game') and the *dynamic profile of interaction*, that is, the development of the interaction over the 3 sessions.

### *Jerry: case study no. 1*

Jerry is 5 years and 10 months old. In the preliminary meeting, he was immediately interested in the 'keyboard that answers', and passed quickly from surprise (Aha effect) to a more careful and analytic approach, commenting aloud: 'It repeats . . . but isn't exactly the same'. His interest in the new 'instrument' was stimulated, among other things, by a knowledge of musical instruments uncommon in children of this age group: his drawing included a wide range of instruments (drums, guitar, flute, violin, trumpets), and from the parents' questionnaire we learned that he listens to classical music. The 'technological' aspect, on the other hand, seems to have taken second place. He wanted to manage his 'meetings' with the machine by himself. Jerry asked to start the first session in pairs, with the Continuator, and then he asked to stop. In session 3 he asked to start by playing alone with the system.

The order of the 'games' was as follows:

| Session | Tasks |
|---|---|
| 1 | 4 |
| 2 | 1, 2, 3, 4 |
| 3 | 2, 1, 4, 3 |

### Attention span

By 'attention span' we mean the subjects' tendency to persist in their contact with the objects or activities, irrespective of any underlying aim. Jerry's attention span was measured for each task, as shown in Figure 3. In the first session, Jerry chose to perform only task 4, one of the tasks that lasted the longest. In session 2, though, he clearly preferred task 2, alone with the system, and this was the task that went on for the longest of all, performed with great concentration. In session 3 Jerry was again interested in working with the system alongside a friend, and even though task 2 was again the longest, the difference between tasks 1 and 4 was very small. His attention was almost identical in sessions 2 and 3 when he played alone without the Continuator (task 1), and then with a partner and the Continuator (task 4). Nevertheless, when playing alone Jerry often appeared to get bored, stopping frequently and sometimes waiting for the system to reply.

An unexpected result was the shorter length of the task involving the partner but without the Continuator (task 3), where the children seem to have had less fun and did not listen so carefully. The system therefore appears to motivate not only individual children, but also those working in pairs, thus stimulating the socialisation aspect of the musical experience.

To conclude, then, the attention span analysis would lead us to hypothesise a greater interest on the part of Jerry in the tasks involving the system, especially when playing alone.

### Dynamic profile of interaction

We will now consider the analysis of various fragments that show the dynamic evolution of the interaction between Jerry and the system over the three sessions. Jerry tended to

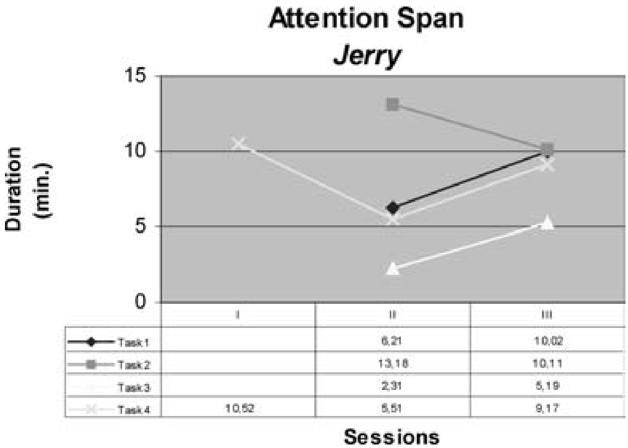



Fig. 3 Jerry's attention span. The session numbers are shown on the horizontal axis, the duration in minutes on the vertical axis

(a) (b) (c)

Fig. 4a/b/c Session 2, task 2: (a) Jerry plays with one finger only, then (b) listens to the Continuator, then (c) plays again using all his fingers

start immediately, displaying concentration and analytical behaviour: he observed and experimented with the rules of the system. To illustrate this conduct, we will start with a fragment taken from session 2.

**Concentration and analytical behaviour** *Session 2, task 2 (Figs. 4a/b/c).* Jerry proceeds by trial and error, respecting the turn-taking with the system. He starts by systematically playing first with his index fingers, then two fingers, then with the palm of the hand, exploring the whole range of the keyboard. The procedure develops in a linear fashion, almost going from the simple (one finger, middle register) to the complex (two fingers, the palm, etc.; middle, low and high registers). He always stops and listens to the system's reply (turn-taking). He listens carefully, unhurriedly, with a concentrated expression. He behaves like an observer introducing variables and trying to understand the results. His relationship with the system might be called 'symmetric', a definition used by Fogel (2000) for the face-to face communication between mother and child. In our particular case, though,

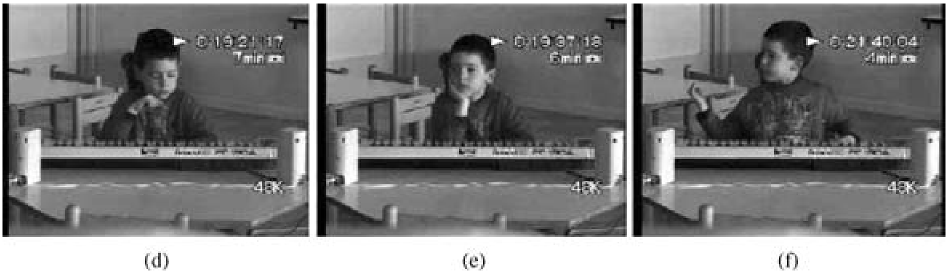



Fig. 4d/e/f Session 2, task 2: (d) Jerry recognises his own notes played by the Continuator, then (e) a musical dialogue starts based on repetition/variation; (f) the dialogue ends

there is not yet any real dialogue between the two partners: Jerry systematically introduces new elements, eager to deepen his exploration of the system, but the replies given by the Continuator do not always reflect Jerry's input.

**Repetition and variation: the dialogue** *Session 2, task 2 (Figs. 4d/e/f).* After some minutes, Jerry 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 as 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. It is interesting to observe how this type of interaction seems very close to that occurring between an adult and a child: 'in the exchange and vocal games [of the child] with the mother, the maternal voice . . . acts as a sound mirror that reflects the vocal experiences of the child and reinforces them' (Imberty, 2002).

In our example, when the system's replies became very varied and the mirror effect vanished, Jerry lost interest, the dialogue ceased, and he asked for the game to stop.

**Listening automatism** *Session 3 (Figs. 4g/h).* Jerry asks to start the game alone with the system (task 2). He starts a strict dialogue with the system, consisting of exploration, repetition, variation. Jerry plays the first phrase of 'Frère Jacques' (C-D-E-C/C-D-E-C), the system repeats with variations (C-D-E-F-G-A-B . .). During the next game, without the Continuator (task 1), a sort of 'listening automatism' is instigated: Jerry knows the system is not connected, but still plays and then stops, automatically waiting for the Continuator to reply, which does not happen. Jerry starts playing again alone, but still waits every now and then for a reply (e.g. he puts his hand to his ear). A kind of automatic expectation has been instituted. The somewhat sad expression that appears on his face, his head leaning


(g) (h) (i)

Fig. 4g/h/i Session 3, tasks 2, 1 and 4: (g) Jerry faces the Continuator (task 2); (h) he plays, then listens, but the Continuator does not reply (task 1); (i) Jerry observes the surprise of his friend on hearing the reply of the Continuator (task 4)

on his hand (Fig. 4h), shows his emotional anticipation, part of a more general affective relationship that the children had established with the Continuator, which they treated with care and attention, just like a playmate, as if the machine were human, or at least a living creature: 'it answers by itself' was the most frequent comment heard during the performances of the system. Jerry's sad expression brings to mind certain descriptions of 'attachment' observed in children at school when separated from their mothers. The reference to the theory of attachment is also suggested by applications of this theory in the field of artificial intelligence, for example to the virtual animal-toys Tamagotchi or Aibo (Kaplan, 2001).

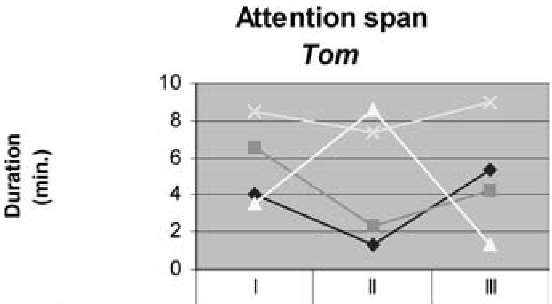
**The observer** *Session 3, task 4 (Fig. 4i).* The interaction continues in the following task (4). Jerry plays with another child. This time Jerry does not only observe the system, but also his friend's interaction with the system: he tells him to play, to wait for a reply from the system, and watches his reaction of amazement. In this phase Jerry shows some moments of excitement.

### *Tom: case-study no. 2*

Tom is also 5 years 10 months. He soon becomes involved in the sound, and learns very quickly how to interact 'in real time' with all the stimuli that he receives from the system and from the whole set of equipment (computer, loudspeaker, expander, wires). He manages with ease to integrate all the various elements into the games with the keyboard and his partner. Once again the parents' questionnaire provides useful information, telling us that Tom knows how to work the TV and the computer. Very significantly, in his drawing he shows the computer, the wires, the loudspeakers and the expander, just as meticulously as Jerry drew the musical instruments.

The order of the games was as follows:

| Session | Tasks |
|---|---|
| 1 | 2, 1, 3, 4 |
| 2 | 4, 3, 1, 2 |
| 3 | 1, 2, 4, 3 |




| | I | II | III |
|---|---|---|---|
| Task 1 | 4 | 1,33 | 5,38 |
| Task 2 | 6,52 | 2,31 | 4,29 |
| Task 3 | 3,55 | 8,57 | 1,31 |
| Task 4 | 8,52 | 7,39 | 9 |

Sessions

Fig. 5 Tom's attention span. The horizontal axis shows the sessions, the vertical axis the duration in minutes

### Attention span

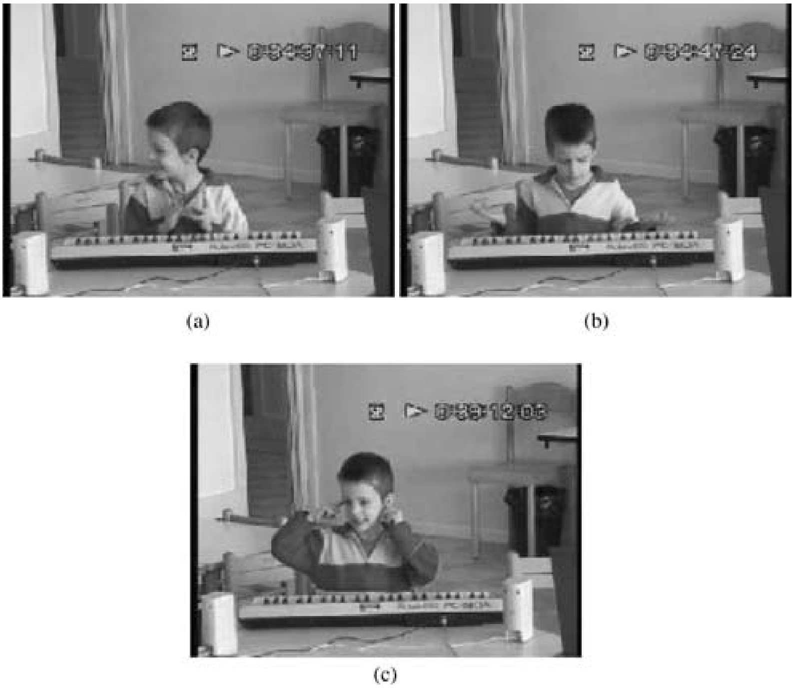
Right from the first session we can see that task 4 (with another child and the Continuator) lasted the longest (Fig. 5), its duration remaining fairly constant throughout the following sessions, even though the time spent on the other tasks varied considerably: in session 2, task 2 was the longest (of all the sessions), while the length of the others decreased. On the other hand, in session 3 task 2 was much shorter, while the others increased.

The fact that task 4 lasted the longest, not only in sessions 1 and 3 but also in terms of the total overall time for each task (1 = 11.11; 2 = 11.52; 3 = 14.22; 4 = 25.31), confirms the trend, already noted in Jerry, that the system enhances socialisation and the sharing of the experience. In Tom's case, task 2 was not always very long but was quite significant in that his attention was completely captured, leading to rich interaction with the machine. Nevertheless, unlike Jerry he showed a general preference for the interaction involving all three participants: himself, his partner and the system.

### Dynamic profile of interaction

Tom soon achieved a good level of dialogue with the system, learning how to make it imitate him and how, in turn, to imitate the system. In the last session, as we can see in the following examples, he reopened his dialogue.

**Surprise and assessment** *Session 1, task 2 (Figs. 6a/b/c).* He plays a few notes, the Continuator replies. Tom recognises the repetition and shows surprise and excitement. The next reply of the Continuator is much longer than expected and Tom shows disappointment, saying 'It never ends'. He nevertheless waits for the system to stop before playing again, thus respecting the implicit rule of turn-taking. There follows a series of improvisations during



(a) (b) (c)

Fig. 6a/b/c Session 1, task 2: (a) Tom recognises his own notes played by the Continuator (surprise and excitement); (b) Tom listening to the long reply by the Continuator: 'Non si ferma' ('It never ends') (turn-taking); (c) Tom puts his fingers into his ears when the system repeats the same note like a blocked machine

which Tom uses various styles and listens carefully. At a certain point the Continuator begins to repeat the same note continuously, as if the machine were stuck (maybe actually due to an error in the working of the system). Tom notices something is wrong and blocks his ears with an expression of irritation.

**Excitement and learning by 'immersion'** *Session 1, task 4 (Figs. 6d/e/f/g/h/i).* Tom teaches his friend the rules: play, wait and listen to the reply, as the keyboard 'plays by itself'. An intense moment of interaction begins: they play and listen, bringing their ears closer to the speakers; they play with their hands, heads, bottoms; they even introduce the ringing of a cell-phone into the game. The rules apply, but also listening, touching, discovering, playing, having fun, provoking amazement and pleasure. Tom often imitates his friend. They discover that the system repeats what they play and learn how to make the system imitate them: the most exciting game is to produce strange sounds (brief sequences of strong, fast and irregular clusters) for the pleasure of hearing the Continuator repeat them – just like laughing at your funny faces in the mirror. *The moment of excitement also becomes the moment of learning* (learning by 'immersion': Maragliano, 1999).

(d) (e) (f)

Fig. 6d/e/f  Session 1, task 4: (d) Tom stops his friend and teaches him the rules of the system and turn-taking: 'Suona da sola' ('It plays by itself'); (e) They use the ability of the system to imitate the sounds they produce in order to enjoy themselves: they play funny sounds with the aim of (f) exciting and sharing the excitement, listening to the equally funny reply by the Continuator

(g) (h) (i)

Fig. 6g/h/i  Various interactive conducts of Tom and his friend: (g) They listen to the speakers, (h) play the keyboard, with the Continuator and the phone; (i) they both play and move their heads in synchronisation

**'Dead moments'** *Session 2, task 4.* During this phase Tom and his partner interact with the system, but from afar. They speak to each other while the Continuator is playing, as if not wanting the system to hear them. They then approach the machine, look beneath the keyboard, and 'bite' the wires. They begin to play again, but not together; they pause, Tom plays restlessly, his partner seems to be looking for something, makes several attempts on the keyboard, plays with his head, his behind, tries out some short rhythmic and melodic patterns, the system replies with just a few notes, while Tom looks through a book. The interaction could be said to be passing through a moment characterised by a slowing-down in the turn-taking, a discontinuity of attention, irregular exploration and a sort of disorientation. The function of this moment is perhaps to allow the children to readjust their approach to the interaction, which is soon taken up again with a new type of game. We have called this phenomenon the 'dead moment', or 'readjustment', due to its functional similarities with what Stern speaks of, using the same terms, as a period of adjustment in the interaction between mother and child (Stern, 1985).

(j)

Fig. 6.j From turn-taking to role-taking: Tom plays the C5 just played by the system in reply to the C1 played by Tom (session 2, task 2)

**From turn-taking to role-taking** *Session 2, task 2 (Fig. 6.j).* Tom plays with more concentration and analytically; he tries to understand the system by looking at the screen of the computer. He plays short musical improvisations. He does not explore, he immediately creates music with the Continuator: they play short rhythmic and melodic patterns, repeat and elaborate them, then play short but complex musical phrases. At a certain point he moves towards the lower register and plays C1. The system responds with C4-A5. Tom recognises that the system has played the same note as he had but at a higher register and says ‘High’; he then goes to the upper register and, imitating the system better than the system had done with his proposal, plays C5, and then goes away saying ‘Finished’, while the Continuator plays Bb-A.

Tom has understood the system, has played with it, has learned to make it imitate him and to imitate the system. It is here, then, that 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 takes the partner into account and as a consequence regulates their own behaviour according to that of the other. Children are, for example, able to adapt their language when speaking to children younger than them (Emiliani & Carugati, 1985).

**‘Attunement’ and climax** *Session 3, task 2*. Tom begins the last session by playing energetically, the Continuator replies with similar intensity; Tom relaunches softly and delicately, the Continuator responds with soft and slow notes. For a while they adapt to each other, not with exactly the same notes, but adopting the same ‘mode’ of playing and following the sequence of question – answer – relaunch. A written description, time frame analysis, and formal structure of the dialogue are provided in Figure 7.

What strikes one most of all in this sequence is the regularity in the timing of each turn, and the fact that both ‘partners’ follow the same dynamic pattern: first *forte*, then *decrescendo* and weak, and finally *forte* again. The overall effect, underlined by the expressions appearing on Tom’s face at each step, is one of strong initial impetuosity that is slowly subdued, becoming softer and calmer, but then returning to the initial energy, and concluding with a reinforcement. It is interesting to note the formal structure of the

| Total time: 37 seconds.<br>The turns last around 1 second each, apart from the last ones, which take about 5 seconds each. A very short pause (less than 1 second) sometimes precedes Tom's turn. | | |
|---|---|---|
| **sec.** | **Written description** | **Formal structure** |
| 0.00 | Tom starts by playing energetically with a cluster of notes, *forte* the Continuator replies with a loud cluster short pause | **a + a** |
| 0.03 | Tom repeats the same thing so does the Continuator | **a + a** |
| 0.06 | Tom plays a *glissando*, again loudly the Continuator plays a few notes, loudly short pause | **b + b′** |
| 0.09 | Tom plays two *glissandos* simultaneously, *decrescendo* the Continuator plays a short sequence of several notes, continuing the *decrescendo* short pause | **b″ + b‴** |
| 0.12 | Tom delicately plays 1 note *ppp*, in the middle register, and listens to the Continuator's reply: two notes, *ppp*, in the lower reg | **c + c′** |
| 0.15 | Tom starts playing note clusters again, energetically, agitated, *forte* The Continuator replies with loud clusters | **a + a** |
| 0.17 | This type of exchange is repeated three more times Tom listens to the 'angry' reply and proceeds with an irritated and defiant expression on his face. He puts too much energy into his playing and hurts his elbow | **a + a**<br>**a + a**<br>**a + a** |
| 0.26 | The 5th time Tom's input is much longer, then he gets up to look at the computer screen The Continuator's reply is also longer | **a′ + a′** |

Fig. 7 'Attunement' sequence

overall *dialogue*:

| |
|---|
| **A** (a + a a + a b + b′ b″ + b‴) |
| **B** (c + c′) |
| **A′** (a + a a + a a + a a + a a′ + a′) |

We are witnessing the creation of a true and proper musical sentence, with questions and answers, repetitions of short phrases, intermediate variations in dynamics and density, giving rise to an overall ternary structure, ending with a finale that presents all the qualities

(k)

Fig. 6k  Session 3, task 2 – climax: Tom plays and moves quickly between the keyboard and the computer

of musical finali: repetition, increased intensity and longer duration. The musical structure has its origins in the form that the dialogue between Tom and the Continuator takes on over time: the rules governing the interaction (turn-taking, regular timing turns, imitations, variation, contrast) also become musical rules.

In this sequence, the system seems able not only to mirror the notes played by the child, but also to some extent to reflect his affective and dynamic profile. We would not, of course, wish to infer that a machine could have the intentionality of a human. What allows the machine to behave in this way is also the speed with which it is able to adapt to the child's input and to produce a suitable reply. Without this ability a situation such as the one described above could not exist.

Since we are not simply dealing with a matter of repetition/variation, but rather with a situation that is more complex on account of the dynamic, formal and temporal aspects taken into account, where musical form and emotional experience proceed in a reciprocal and parallel fashion, we have called this phenomenon 'attunement', due to certain similarities with the 'affect attunement' described by Stern in the interaction between mother and child. This phenomenon features a type of imitation that is not simply the repetition of the manifest behaviour of the child, but is to a large extent transmodal, being based on the correspondence of a state of mind (inferred or directly understood), and is a process that takes place extremely quickly, with regular timing turns. The three dimensions of such correspondence are essentially musical qualities: intensity (vocal or kinetic), rhythm and form (Stern, 1985).

After this phase of 'attunement' the dialogue is resumed. Tom gets up, jumps from the computer to the keyboard, and his movement is mimicked in the music he and the system play (Fig. 6k). Delightful and amusing to see, it is truly a moment of genuine creativity. Tom is no longer exploring the system, they are making music together – a real jam session.

**Relaunching** *Session 3, task 4.* In the final session, Tom relaunches the repeated notes that he had considered a fault in the machine during the first session. A three-sided interaction is set up based on this musical idea: sequences of two notes repeated rapidly, slowing down, speeding up, followed by clashes between the groups of notes played by Tom in the middle range and single notes repeated in the high register by his partner, interspersed with occasional moments of synchronisation when they both follow

(l)

Fig. 6l Session 3, task 4: Tom and his friend are defusing the 'bomb' (Roland expander) under the table. They play and watch the lights on the screen of the expander

the same pulse. The Continuator replies with a long sequence using a single repeated note, which stimulates the children and prompts them to carry on with this new musical idea. It is interesting to see how Tom develops a musical idea that stemmed from an error of the machine, thus turning it into a 'creative error'.

This particular performance of task 4 provides a good instance of 'scaffolding', where the Continuator not only re-proposes the musical ideas to the child who first produced them (as happened in the individual sessions), but also 'refracts' them on the other partner, and in so doing encourages both children to contribute to the building up of an overall musical construction. This is a fine example of how to set up group improvisations.

The session concludes with a relaunching of the previous explorations, interspersed with pauses when they discuss what to do. Their finale offers a triumph of technology: the Roland expander, with its lights, becomes a bomb to be defused (Fig. 6l).

### *Discussion*

In the two case studies presented above we can observe an interaction between the children and the system that builds up over time, passing through various dynamic states which do not necessarily follow a linear order. We shall now underline the significant aspects of these two cases, interpreting them in the light of developmental theories and more especially of musical development in children. The interpretation of these two case studies allows us to give some answers to the questions raised at the beginning of this paper regarding the nature of interaction between a child and a machine, especially with the particular system used in this experiment.

#### Nature of the interaction

The two case studies would suggest that the Continuator is able to develop interesting child/computer interaction, very similar to that between humans. This phenomenon seems to have its origins in the ability of the system to replicate the musical style of the children. The interaction based on repetition/variation allows the children to organise their musical discourse, passing, as in the case of Tom, from exploration to genuine musical invention. In particular, we note that the moment of climax arrives when the two partners adapt to each other's 'style' of producing sound and accelerate the times of the turn-taking; once this has been achieved the interaction is concluded, almost like a gesture of liberation from the accumulated tension. A similar structure based on repetition and variation, pauses for readjustment, and temporal dynamics has also been observed by Stern (1985) in the vocal relationship between mother and child, and by Imberty (2002) in the field of music. Similar interactions have been observed recently in young children and adults playing a xylophone (Young, 2004): this kind of interpersonal dimension is a potential source of musical creativity for young children. The very fact that the interaction is so similar to that of humans may perhaps explain why the children find it so exciting: just like in cartoons, where the thing they like most is that 'it seems real because it's fake' (Mattia, 3 years old, in Mazzoli, 2001).

In fact, despite the apparent simplicity of the mechanism, the Continuator generates very complex reactions, where the children are expected to form judgements about 'self' and 'other', and to assume the point of view of the other in order to judge their own self. In the literature these passages are considered crucial for the building of the child's self: the Continuator, by means of its mirror effect, could be said to represent the construction of a 'musical' self, or, in the words of Turkle (1984), a 'Second self', where not only the machine seems to 'think', but also think like the user.

### Rules of the system and musical rules

The children learned the rules of the system: it replies by playing alone, it replies when you stop playing (turn-taking), repeats what you play, repeats with variations (or 'errors'), is capable of establishing a dialogue made up of repetition/variation, it does not always respect the rules, you can teach the system, and the rules of the system can be taught to others. During this process the children reacted if the system did not respect the rules: Tom showed disappointment when the system began to repeat the same note like a blocked machine, and corrected it when it repeated inaccurately what he had played. In the end, though, he reused an error of the system, the repeated notes, to invent music.

We observed two kinds of learning style. In the first case study Jerry learned the rules of the system in a 'linear' way, moving from the simple to the complex, by trial and error; in the second case Tom learned to use the system by putting all his senses into his involvement with the system and other instruments, and as a result the moments of excitement and learning coincided. We are witnessing two different styles of learning, which have been defined as 'linear' and 'by immersion'. The former is more typical of the technologies associated with writing, such as books, while the latter is more linked to multimedia technologies (Maragliano, 1999; Mazzoli, 2001). In both cases the system has stimulated a learning strategy for problem solving: during the interaction the children not only identified the problems of interacting with the system, including the rules governing musical language, but discovered a solution to these problems too.

### In pairs or alone, with or without the Continuator

The two tasks involving the system gave rise to the longest attention spans and showed how most children reach a stable level of attention characterised by a strong and continuous interest in the interaction. The time also increased considerably in task 4 when the two children played with the system. The system therefore appears not only to motivate individual children, but also children working in pairs, thus stimulating the socialisation aspect of the musical experience. These data, together with the phenomenon of Surprise and Excitement observed, could be interpreted as signs of *intrinsic motivation* that stimulated the children's interest and pleasure in using the machine and its musical and interactive games. 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, which are normally less attractive to such young children (McPherson, 2002).

### Listening

The listening conducts are particularly rich and varied: concentrated, analytical, but also symbolic and creative. The children often 'dramatise' the sounds they hear, giving them a narrative form or an expressive representation. We can see here an important difference regarding the educational strategies of mirroring, modelling and scaffolding described by various authors, where the sound is just one perceptual channel among others. In our case hearing is the main channel, and at times the only one, through which the children communicate with the system. This factor gave rise to some particularly careful and prolonged bouts of listening, encouraging the children to 'think in sound'. A further significant aspect is the quality of the children's listening to their own productions while they played, heightened by the interactive element that encourages them to listen carefully so as to compare their own pieces with the reply and new proposal of the system, and to identify repetitions and differences. As has already been reiterated many times in the world of teaching, listening to one's own musical productions while playing is one of the main objectives of music education (Delalande, 1993; Frapat, 1994). The quality of the child's explorations, improvisations, compositions and performances depends essentially on the child's ear, and it is this aspect that prompts the child to reproduce an invention, vary it, play with the variation and create special effects.

### Music-makers with style

The system stimulated and reinforced conducts of an explorative type, during which the child's actions were coordinated with the purpose of exploring the new partner, and which were characterised 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.[2] Both in the exploration and in the improvisations themselves, we can see very personalised styles in the children's 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 Continuator is able to reinforce these individual styles, and allows them to develop and evolve. We have observed that the 'teaching method' is based on turn-taking and regular timing turns, on the strategies of mirroring, modelling 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. In case study 2, in particular, we see how the system teaches the child to play with it, by guiding him from exploration towards musical invention, just like a real teacher. The analysis of these two case studies has provided us with a basis on which to perform a systematic study of the improvisations of the other children who participated. The way the children play also shows their stylistic competence, not only as listeners, as previous research has found (Addessi *et al*., 1996; Hargreaves & North, 1999; Marshall, 2001), but rather as music-makers: Tom played standing up, moving a lot, his sleeves pulled down over his hands, displaying an intense physical relationship with the instrument; Jerry always played while seated, in a composed state. The questionnaires tell us that Tom's father is an expert in rock music, whereas Jerry listens to classical music.

### The Continuator as a flow machine

Finally, in case study 2 it is possible to recognise the conditions described in the theory of flow by Csikszentmihalyi (1990): distractions are excluded from the consciousness; action and awareness are merged; there is immediate feedback to one's actions; step by step, the activity becomes autotelic. The notion of flow defines the so-called 'optimal experience' as a situation in which people obtain an ideal balance between skills and challenges. We can say that in both case studies a balance between challenges and skills is achieved. Other states can also be described in terms of the balance between skills and challenges, such as anxiety or boredom, but the flow state is fundamental in order to develop creativity. We might think of the Continuator as a flow machine in the sense that it produces a response corresponding to the skill level of the user (see Pachet & Addessi, 2004 for further discussion).

## Conclusion

In this paper we have presented a study carried out at the University of Bologna about children working with a particular interactive system, the Continuator, created at the Sony-Computer Science Laboratory in Paris. We have described the setting in which our observation took place and offered an analysis of two case studies. The results provide some important categories for further observation and interpretation of data and make it possible to formulate various hypotheses about the nature of the interaction between children and interactive systems, in particular between children and the Continuator.

The Continuator would appear to be able to elicit interesting child/computer interaction, and seems to activate interactional microsystems similar to those observed in infant/adult communication (we refer in particular to Stern, 1995 and Imberty, 2002), but with a more mechanical and computational approach (Turkle, 1984), which would perhaps explain why the children found it so exciting. The system's ability to maintain the children's attention for long periods of time, remarkable for this age, together with the phenomenon of Surprise and Excitement observed, suggest that while interacting with the system the children reach high levels of well-being and creativity, similar to those described in the theory of flow (Csikszentmihalyi, 1990). As such, the Continuator is just one instance of a larger class of systems that could be called *reflective*, in which users can play with virtual copies of themselves, or at least agents who have a mimetic capacity and can evolve in an organic fashion. We believe that most of the interesting properties highlighted in our experiment probably stem from this particular characteristic. From this point of view, the system has proved to be an excellent research tool for studying the genesis of the processes of invention and musical interaction in children.

From a pedagogical point of view, one of the most significant results is that the children are helped to develop very attentive listening skills, as well as creative musical conduct and a personal music improvisation style, based on their own ability and musical knowledge. This, in our opinion, is no small result, since despite its great importance, the teaching of improvisation is still rarely tackled in Western formal music education (McPherson, 1994; Kenny & Gellerich, 2002).

As far as the use of new technology for the purposes of music education is concerned, we think that the encouraging results obtained were also due to other features of this kind of system. A full analysis of the properties of reflective interactive music systems as tools for enhancing creativity can be found in Pachet (2004). We shall limit ourselves here to pointing out some of the most obvious features. First of all, the children only interact by playing, without other graphic or mechanical interfaces (e.g. mouse, buttons, switches, etc.). The system therefore possesses the properties of *transparency*, involving 'a shift from the representation of music to the music it self' (Folkestad *et al*., 1998: 95), and *reflection*, in the sense that it is the system itself that helps the user to understand the mechanism of interaction. Second, it avoids the monotony of mere repetition: inane repetition has been indicated as one of the negative aspects of many automatic systems (De Kerckhove, 1993). Third, it is not programmed with fixed musical objectives (e.g. ear training, chord recognition, etc.), and therefore fosters the pleasure of not knowing what will happen. Finally, the children's timing seems to be respected: the overall interaction remains fluid, passing through moments of serious concentration, but also moments where the interaction dwindles. Furthermore, the children are able to interrupt the game when they want, thus preserving the factor of 'distance' between child and machine, vital from an aesthetic and pedagogic point of view (Bertolini & Dallari, 2003).

We are now preparing an observation grid to analyse the performance of all the children that took part in the protocol and to check the categories established so far, including the influence of age. We are analysing the musical improvisations in detail and checking all the psychological states described by the theory of flow.

In the light of these results, the project foresees the experimentation of new protocol for interaction and new variants to be applied to interactive reflective musical systems. We believe an approach consisting of the close integration of psychological experiments and system design to be very productive and one that should be pursued.

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## Notes

1 French: *conduite*; Italian: *condotta*; German: *Betragen*; English: *conduct*. The term appears above all in the literature of countries with Latin-based languages and is often used as a synonymn of 'behaviour'. However, 'It can be distinguished from the latter in that behaviour refers to the set of habitual actions and reactions of an organism in an environment where objective observation is possible, whereas conduct refers to a deeper interior level where these actions and reactions originate' (Galimberti, 1992: 214). Piaget defines conducts as the 'behaviours, including the conscience' (Piaget & Inhelder, It. 1970: 7). In the musical field the concept has been used by Delalande (1993): 'Reasoning in terms of conduct as opposed to behaviour means trying to understand the function of the acts. When someone picks up their instrument, prepares to play and then plays, what are they looking for, what do they expect from this set of coordinated actions? It is the purpose itself that helps us define the musical conduct' (p. 45).

2 The distinction between exploration and invention is not always clear cut, and from a theoretical point of view scholars are not in agreement on this matter. Our standpoint is based primarily on what we have observed, and takes inspiration from the differences proposed by Delalande (1993) and Frapat (1994) between *exploration* and *invention*, and by Kratus (1994) between *exploration* and *development*.

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### Musical examples

created by the Continuator can be found on the web site, www.csl.sony.fr/~pachet, and will be included on the next *BJME* CD.