Child/Computer interaction: Observation in classroom setting

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In: R. Parncutt, A. Kessler & F. Zimmer (Eds.)
Proceedings of the Conference on Interdisciplinary Musicology (CIM04)
Graz/Austria, 15-18 April, 2004 http://gewi.uni-graz.at/~cim04/

Background in music education: The relationship between new technology and learning is gaining more relevance in the field of music education (Webster 2002). The present study deals with an area still under-studied, that of *interactive musical systems*, in an attempt to understand in what way it can affect the learning and the musical creativity of children. In particular, we chose to study young children, 3/5 years old, because at this age the problem of the interaction between child and machine takes on a fundamental role in the learning process. Imberty (2002), in accordance with the psychologist Daniel Stern (1977), describes the musical development of young children as based on the vocal play between child and mother (lallation, baby-talk), characterised by the mechanism of repetition and variation. The point of interest is to verify what type of music development arises when this interaction takes place not between two human subjects, but rather between a child and a machine.

Background in artificial intelligence: At the Sony CSL, a system was elaborated able to produce music in the same style as the person playing the keyboard, the Continuator (Pachet 2002). This system is based on the notion of *Interactive Reflective systems*. 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 performed not by the user, nor by the machine, but by the *actual interaction* between the user and the system. A preliminary experience has been conducted in Paris with eight children of 3 and 4 years, who were invited to play a keyboard and then the keyboard connected to the Continuator. The ability of the system to attract and hold the attention of children can be interpreted through the theory of Flow introduced by psychologist Csikszentmihalyi (1990).

Aims: A second experimental protocol has been established to observe systematically some interesting behaviours observed in the preliminary experience, and to analyse the music played by the children and the system, according to the age of the children (3-5), the exposure to the experience, and if they play alone or together with another child. From a pedagogical point of view, the general aim is to understand in what way the children relate to interactive musical systems, what kinds of musical and relational behaviours are developed, and how interactive systems can be used in the educational field to stimulate creativity and the pleasure of playing.

Method: The experiment was based on observation. It was carried out with 27 children of 3/5 years, in an Italian kindergarten (Bologna). Three sessions were held once a day for 3 consecutive days. In every session, the children were asked to play in 4 different ways: just with the keyboard, with the keyboard and the Continuator, with another child, and both with another child and the Continuator. All the sessions were recorded on video. The attention span of the children was measured for each task. Two case-studies were observed and analysed. Successively, the most interesting conducts were selected to be tested also on the other children by means an observation grid.

Results: It was possible to observe a sort of *life cycle of interaction*, that move from surprise, to a different phases of excitement, analytical behaviour, invention, readjustment and relaunch. The two tasks involving the system gave rise to the longest attention spans and show how most children reach a stable level of attention characterized by a strong *intrinsic motivation*. The system therefore appears to motivate also children working in pairs, thus stimulating the socialization of the musical experience (*join attention*). The *listening conducts* were particularly varied: the child listen carefully to their own productions in order to identify repetitions and differences with the replies of the system.

Conclusion: The results suggest that the Continuator, or other similar *interactive reflective systems*, is able to develop interesting child/computer interaction and creative musical conducts in young children, thanks above all to its ability to replicate the musical style of the child that is playing.

The relationship between new technology and learning is gaining more relevance in the field of music education (Webster 2002). However, only a few studies have considered the "nature" of the interaction between children and musical machine. The present study deals with an area still under-studied, that of *interactive musical systems*, in an attempt to understand in what way it can affect the learning and the musical creativity of children. In particular, we chose to study young children, 3/5 years old, because at this age the problem of the interaction between child and machine takes on a fundamental role in the learning process. An experimental protocol was established to observe selected conducts in children confronting an interactive musical system.

This article will present the background to the two disciplines, the experimental protocol, and a part of the results. These will be followed by a discussion and the conclusion.

Background in music education

The term *media education* refers to the field of study that deals with the relationship between new technology and learning. This relationship has been studied from different points of view: the learning content and concepts particular to a subject area (i.e. in music, programs for learning how to write music and how to teach concepts such as pitch, melody, timbre, etc.), further elaboration of this knowledge (i.e. programs for composing music), or programs for creating hypermedia based on images, animations, music, vocal and other sounds which aid the listener in learning concepts through games (*edutainement*) (Webster 2002). The majority of the studies carried out until now deal with children of 8 years and older and regard the didactic use of new technologies, or else technologies that serve as "transparent" instruments that allow for the making and producing of music (*music-maker*), also without attending specific courses of music composition (Folkestad 1996; Folkestad et al. 1998). Many studies have also documented the impact new technologies have had on the curriculum of music education and its teaching methods, (see *British Journal of Music Education*, 14/2, 1997; *Les Dossier de l'ingénierie éducative 43, 2002*).

The subject of media education also has a more theoretical aspect regarding the relationship between new technological language and the development of knowledge (De Kerckhove 1993, Turkle 1984). Music education is not immune to these problems. New technologies are creating new ways of listening as well as "new environments", that are understood as the surrounding spaces in which children develop the processes of music learning and perception, characterized more and more by the "presence" of TV, play-stations, internet, and still even today by radio and movies (Mazzoli 2001, Maragliano 1999).

It is therefore necessary to consider new technologies in the field of music education not only as "instruments" for didactic support, but also as languages and experiences that affect, form and shape profoundly the processes of music learning and the musicality of children.

Within the issues presented above is an area still rather under-studied, that of interactive musical systems. With interactive systems, the problem of the interaction between the child and the machine takes on a fundamental role. Recent experiments have been carried out that look at the interaction between children and technology, in which the use of "sensory" spaces allowed the children to interact creatively with music, their own body, and a robot (Camurri & Coglio 1998; see also GRM 2000, MusicLab 2002).

According to some developmental theories (Bowlby, Fogel, Stern), the mother/child relationship and communication has an important role in the affective and cognitive development of the child. In the field of music development, Imberty (2002), in accordance with Stern (1977), describes the musical development of a child as based on the mechanism of repetition and variation. The problem presented is therefore which models of development are produced when these forms of relationships are established not between two human subjects, but rather between a child and a machine. The "inane repetition" of many automatic systems has been indicated as one of the "negative" aspects not only of interactive machines (games, play-stations, etc.) but of mass-

media in general (Bertolini, Dallari, 2004). This is not a matter of moral judgments on new technologies, but rather the understanding of a phenomenon that is an integral part of our culture.

As we shall see below, the potential monotony of mere repetition is to a large extent avoided in the system chosen for our experiment.

Our research is characterized by two elements:

- the relationship between musical education and new technologies is examined from the point of view of the "interactivity" of a musical system.
- the age of the children that we intend to observe, 3/5 years, is still quite under-studied.

Background in artificial intelligence

At the Sony CSL, a system was elaborated able to produce music in the same style as the person playing the keyboard, the Continuator (Pachet 2002, 2003). An important consequence of this approach is that the phrases generated by the Continuator are *similar but different from* those played by the users, like a sort of sound mirror. This system is based on the notion of Interactive Reflective systems. 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 performed not by the user, nor by the machine, but by the *actual interaction* between the user and the system.

The main focus of the Continuator project was initially to design a system for adults, either beginners or professionals, and feedback from adults was systematically sought and analysed. The project had however unexpected ramifications in the domain of musical education for the early ages (3 to 5-years old).

To illustrate the working of the Continuator, some simple musical examples are given below. The examples are notated exactly as they are played, i.e. without rhythmic quantization. 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. Issues related to capturing higher-level structure are not discussed here as they are not relevant for our purpose (refer to Pachet 2002 for more details).[1]

The most important aspect of the Continuator is the fact that the musical material generated always conforms stylistically to the input. Also (this is more difficult to illustrate graphically), the Continuator keeps on learning from whatever input is given. As a consequence, the behaviour of the system improves over time: if the user produces phrases which are stylistically consistent, but unique, the Continuator will learn more faithfully and will produce musical phrases that are increasingly accurate, with respect to the musical style of the user.

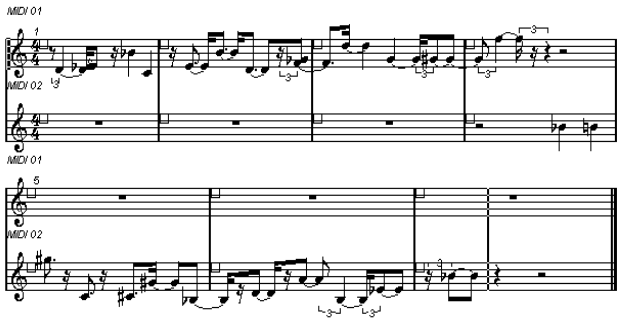

Figure 1. A simple melody (top staff) is continued by the Continuator in the same style.

The basic playing mode of the Continuator is a particular kind of turn-taking between the user and the system determined 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 parameterized, but in most cases the duration is set to be the same as the duration of the last input phrase.
3) Priority given to 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 again principle 1).

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 (MusicLab, 2001; 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 agnostically 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, whatever his skills, competence level, and musical goals, is confronted with some sort of developing mirror of himself. This unusual situation creates strong subjective feelings that we believe can be exploited for enhancing the musical experience and for teaching musical skills in general.

A preliminary experience has been conducted by the second author in Paris with eight children of 3 and 4 years, who were invited to play a keyboard and then the keyboard connected to the Continuator. The goal of these experiments was to test basic hypotheses about the effect of the Continuator on the playing abilities of young children (attention span, surprise, exploration modes, autonomy) (Pachet & Addessi 2004).

The Experimental Protocol

A second experimental protocol has been established to observe systematically some interesting "conducts"[2] observed in the preliminary experience, and to analyse the music played by the children and the system, according to the age of the children (3-5), the exposure to the experience, and if they play alone or together with another child.

In this phase of the project we observed just a small number of children: this will serve both to obtain some observable and interpretable data and to define the procedure. Twenty-seven children aged 3/5-years participated in the trial.

The observation was trialled in the Nursery School "La Mela" of Quarto Inferiore (Granarolo, Bologna – Italy).

Method

Taking into account both the age of the children (3-5 years) and the desire to maintain a setting in which they are comfortable, we chose to use the *observation method* (video recording and photos), which allows us to describe the conducts of the children without changing their daily routine. It is possible to make a controlled observation, according to Piaget's "quasi experimental" model, involving the continual and systematic observation of the *conducts* in the field, and based on various hypotheses, with variables to check (Mantovani 1998). In this protocol the independent variables are the "partners" with whom the children were invited to play (the solo keyboard, the Continuator, another child), the exposure to the experience (once daily for 3 consecutive days), and the age of the children (3-5 years). The dependent variables are the children's musical conducts (listening, exploration of the keyboard, musical improvisation) and the children's interaction with the system (attention span, turn-taking, symmetrical communication, etc.).

We also used:

- *Audio recorder* of the improvisations played by children and Continuator.
- *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 children's psycho-pedagogical profiles made by their teachers were collected.

Equipment. We used the Continuator, a Roland ED PC-180A keyboard as the interface, a Roland expander, a pair of amplified loudspeakers, computer, video camera, digital

camera. The basic playing mode of the Continuator was a particular kind of turn-taking as described before.

Procedure. *Preliminary meeting*: the observation was preceded by short meetings between the operators and the children. During these meetings game activities were made, also involving the keyboard and the Continuator. The aims of the meetings were to present the staff to the children, to get to know the children, and to prepare the children for the experimental activities.

Video and audio recording: in the following days the video observation took place. Video and audio recordings were made in the small library of the school, suitably equipped. In this space the keyboard was placed on a table in front of the children. The portable computer was placed on a nearby table. A video camera (not visible to the child) was positioned in front of him/her, in order to record both the hands and face. One collaborator worked with the video camera while another operator 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, etc), 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 just the keyboard, 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 A**. "Play the keyboard as long as you like. When you are tired, call me" .
> **Task B.** "Play the keyboard, which will answer back, for as long as you like. When you are tired, call me" (For this task the operator launches the Continuator through the computer)
>
> *The child with another child*:
> **Task C**. "Play the keyboard together for as long as you like. When you are tired, call me"
> **Task D**. "Play the keyboard, which will answer both of you back, for as long as you like. When you are tired, call me" (For this task the operator launches the Continuator through the computer).

The tasks were given in random order and all sessions were recorded on video. The music played by the children and the systems were recorded by the same system. After 1 week the children were asked to *draw* the experience.

Participants. The complete protocol was carried out with 9 children: 3 aged 3 years, 3 aged 4 years and 3 aged 5. The other children either took part in the trials in pairs, or in free sessions, which were also recorded on video.

Data Analysis. A series of key elements were identified regarding the child/Continuator interaction, independently of the scansion of the three sessions. Two case-studies were observed and analysed over the tree sessions: the life cycle of interaction. The attention span of the children was measured for each task. Finally, the most interesting conducts were selected to be tested also on the other children by means an observation grid, in order to analyse the development of these conducts over the three sessions. The conducts in the grid are the following: the styles of child/system interaction (turn-taking, role taking, attachment, repetition/variation, rules of interaction); the life cycle of the interaction; the exploration of the keyboard; the music improvisations; the listening; the creativity.

Results

The data analysed until now show a certain number of interesting results, relating to the development of interesting music style interaction between children and system, power of attraction/addiction, increase of time of attention, development of analytical behaviours (e. g concentration and listening).

In this paper the data concerning the life cycle of interaction, the attention span and the listening conducts, will be described and discussed.

The Life Cycle of interaction

Following the first observation of the video recording, it was possible to observe in the children/system interaction an initial dynamic curve that moves from *Surprise* (the *Aha effect*), to a phase of *Excitement*, followed by

a period of C*oncentration and analytical behaviour*. We called this phenomenon the "life cycle" of interaction (Pachet & Addessi 2004):

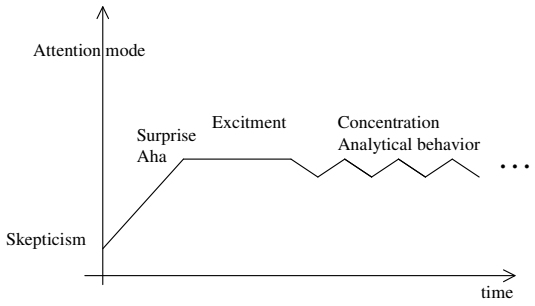

Figure 2. A tentative sketch of the "life cycle" of the interaction mode with the Continuator.

Successively, two case studies were analysed (G. and T.) and we observed 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 (for more details see Addessi & Pachet 2003).

Therefore, we were now able to build the key moments of the life cycle, which are as follows: Surprise and Aha effect, Excitement, Concentration and analytical behaviour (turn-taking, role-taking, exploration, assessment, repetition/variation), Invention, Observer, Readjustment, Relaunching .

Surprise and the Aha effect. The Aha effect, observed in the case of professional musicians (Pachet 2002), was also noticed systematically in children. This surprise was manifested in a variety of facial expressions and gestures, both in single-child and two-children sessions. The term 'Aha' is used in a somewhat biased way here to denote the fact that the children came to a sudden realization that the system was somehow trying to analyse and understand their own inputs, and speak their language**.**

One important point is that this Aha effect rarely reoccurred. After becoming used to the specifics of the interaction, children concentrated on other aspects of their musical relation with the system.

Figure 2. Various expressions of *surprise or Aha*, occurring in early stages of the interaction with the Continuator.

Excitement. We separate here excitement from surprise in the sense that the surprise effect is most often short in duration, whereas the excitement phase lasted much longer, sometimes for 20 minutes or more. Excitement was observed in most of the cases. Interestingly, the children were excited mostly by what the system was playing, rather than by what they were doing. Figure 3 shows some expressions of this excitement.

Figure 3. Various expressions of *musical excitement*. Excitement is mostly provoked by listening to the system, rather than by actually producing music.

In case-study n. 2, the moment of excitement also becomes the moment of learning: T. and his friend discover and create new rules of interaction. They use the ability of the system to imitate the sounds they produce in order to enjoy themselves. This phenomenon is similar to one described by the pedagogist Maragliano (1999) as *learning by immersion*.


4a


4b

Figure 4. *Learning by immersion* (Case-study n. 2, Session II, Task D). T. and his friend create new rules: they play funny sounds (Fig. 4a) with the aim of exciting and sharing the excitement, listening to the equally funny reply by the Continuator (Fig. 4b). Just like laughing while making funny faces in the mirror.

Concentration and analytical behaviour.

In this phase a series of different conducts can be observed, as follows:

- *Turn-Taking.* The child learns the implicit rule of turn-taking. An example (Fig. 6a/b/c): in case-study n. 1 we observe that at the beginning G. starts and proceeds by trial and error, in a linear fashion: first one finger, then two fingers, and then the palm etc.; first middle, then low and high register. He always stops and listens to the system's reply, respecting the "turn-taking" with the system. In case-study n. 2, T. plays with his friend and the system. He stops his friend and teaches him the rules of the system and turn-taking: "Suona da sola" ("It plays by itself") (Fig. 5).

Figure 5. Turn-Taking. (Case-study n. 2, Session II, Task D). "It plays by itself".

Fig. 6. Turn-Taking (Case-study n. 1, Session II, task B). (a) G. plays with one finger only, then (b) listens to the Continuator, then (c) plays again using all his fingers.

- *From turn-taking to role-taking.* Sometimes we observed a transition from turn-taking, that is the alternation between two interlocutors, to role-taking, a term used to imply the ability to consider the point of view of the Other, also about their own Self (Emiliani, Carugati 1985). We can observe an example of this phenomenon in case-study n. 2 (Session II, task B):T. is playing with concentration and analytical behaviour. At a certain point he moves towards the lower register and plays C1. The system responds with C4-A5. T. recognizes 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, plays C5, and then goes away saying "Finished". While the Continuator plays B-A. He plays his own note as played as the Continuator.
- *Repetition and Variation.* The particular ability of the system to imitate the style of whoever is playing generates dialogues based on repetition and variation. Or rather, we observed that a real dialogue between the child and the system actually begins as soon as the child recognizes something from his own proposal in the reply of the system, and tries to answer in the same way: by repeating and varying what he has just heard from the system. An example (Case-study n. 1). At the beginning of Session II, G. starts and proceeds by trial and error, in a linear fashion: G. is trying to understand the system but we cannot observe a real dialogue between child and system yet. After around 8 minutes, a real dialogue starts when G. recognizes his own note played by the system, like in a mirror: G. plays one note at random (G, *staccato*), the Continuator replies with the same note and adds the octave (G3-G4). G. is surprised and immediately replies with the same note and adds a variation (G-G-A-A-B-cluster). A dialogue starts: G. and the system reply and add variations in register, rhythm, modes of playing (Continuator: cluster/rising arpeggio; G.: short cluster; Continuator: cluster, rising 3rd; etc). After around one minute, when the repetition/variation disappears, the dialogue also ends and G. asks to stop game B.
- *Assessment of the system.* The children react if the system does not respect the rules. For example: T. shows disappointment when the system plays longer than expected, not respecting the turn-taking (Fig. 7a); he covers his ears when the system begins to repeat the same note like a blocked machine (Fig. 7b).

7a

7b

Figure 7. The assessment of system (Case study n. 2, Session I, task B. **(a)** T. listening to the long reply by the Continuator: "Non si ferma" ("It never ends"); **(b)** T. puts his fingers into his ears when the system repeats the same note like a blocked machine.

Attachment A sort of listening automatism can sometimes be observed that could be explained in terms of the theory of "attachment" (Bolwby, Ainsworth. Holmes 1994). For example: at the beginning of the task A, G. plays then listens, but the Continuator doesn't reply because in task A the system is not connected. G. starts playing again alone, but still waits every now and then for a reply (e.g. he puts his hand to his ear). A sort of "attachment" is instigated: when I am close to the one I love I feel good, when I am distant I feel anxious.

Figure 8. Attachment (Case study n. 1, Session III, tasks A: he plays then listens, but the Continuator doesn't reply.

From Exploration to Invention. In Session III (Task B), when T. plays with the system, he begins playing energetically, the Continuator relaunches softly and delicately, T. 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. This phenomenon seems to reflect what Daniel Stern defines with the term "affective syntonization" (1977). Then the dialogue becomes more and more intimate. It is truly a moment of genuine creativity. T. is no longer exploring the system: they are making music together. A real jam session.

The Observer. In task (D). G. plays with another child. This time G. does not only observe the system, he observes the surprise of his friend on hearing the reply of the Continuator.

Figure 9. The Observer (Case study n. 1, Session III, task D) G. observes the surprise of his friend on hearing the reply of the Continuator.

Readjustment. During this phase the children 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. The interaction could be said to be passing through a *dead moment*, featuring a slowing-down in the turn-taking, a discontinuity of attention, irregular exploration and a sort of disorientation. The function of this moment seems to be to allow the children to readjust.

Relaunching. At a certain point in the interaction, sometimes after a moment of readjustment, the children start up a fresh phase of interaction by proposing something new (a sound-gesture, a rhythmic pattern, a melodic fragment, etc.). Sometimes this consists of exactly what they had considered an error of the system. For example, during the last session, T. relaunches the repeated notes that he had considered an error. He treats it like a teacher would treat an "intelligent error" made by a pupil.

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. One of the aspects that motivated us to use the Continuator with

children was the observation during the preliminary experiment that the attention span of the subjects tended to increase considerably when the keyboard was connected to the system.

In the protocol in question the attention span of the children was measured for each task (A, B, C and D). As can be seen from the data shown in Fig. 2, tasks B and D (i.e. those involving the system) produced the longest mean times of attention.

The multivariate analysis of variance (MANOVA) was carried out on the repeated measure factors (within) Session and Task, taking the lengths of the tasks as the dependent variable. A significant effect was seen for the factor Task ($F=5.15$; $p<.05$). The paired *t tests* showed the differences between task A and task B to be significant ($t=-3.79$, $p<.01$), as well as the differences between tasks B and C ($t=3.21$, $p<.05$). Borderline values of significance were seen for the differences between tests C and D ($t=-2.30$, $p=.05$). The analysis don't show any significant effect on the interaction between factors Session and Task, and nor was any significant effect found for the factor Session.

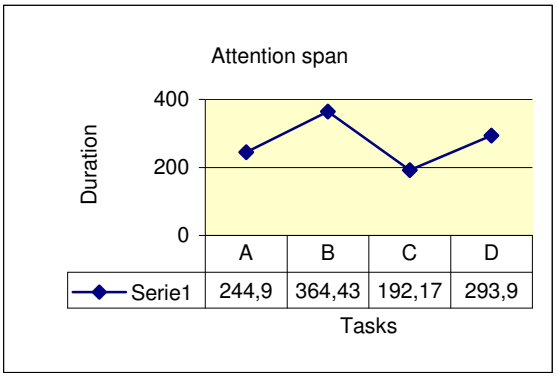

Figure 10. Attention span. Mean values for the four tasks in the three sessions taken as a whole

The two tasks involving the system therefore gave rise to the longest attention spans and show how most children reach a stable level of attention characterized by a strong and continuous interest in the interaction. Task B (child alone with keyboard and system), shows the longest overall span, and the difference was found to be significant not only with task A but also with task C, where the two children played in pairs. The system would thus appear to provide the children with high motivation to interact with the keyboard when playing alone.

An unexpected result was obtained from task C, the task to which the children dedicated the least overall time even though playing in pairs. The time increased considerably in task D when the two children played with the system (the difference is on the borderline of significance). The system therefore appears not only to motivate individual children, but also children working in pairs, thus stimulating the socialization aspect of the musical experience. In fact, a typical situation encountered in sessions involving two children 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 system. This situation, which we call "aspetta" (the Italian word for "wait"), is illustrated in Figure 11.

Figure 11. Joint Attention. " Aspetta ": when one child forces the other to stop in order to listen to the machine.

In addition to these data based on the 9 children who completed the whole protocol, mention should also be made of some of the attention spans observed in the other children who took part in the free session without performing all the tasks. One child, in fact, reached times of 50 and 45 minutes, a duration that is all the more remarkable if we consider the age of the children. A final comment should be made about the quality of the attention, above all in task B, which gave rise to less distractions, greater concentration, pleasure and involvement, and higher levels of exploration, musical invention, and above all of careful listening.

Listening conducts

The listening conducts were particularly rich and varied: concentrated, analytical, but also symbolic. The children often "dramatized" the sounds they heard, giving them a narrative form or an expressive representation. We shall follow the listening conducts of a 4-year-old girl, R., bearing in mind that similar conducts were seen in all the children.

Autotelic listening. Throughout the game R. is always attentive and "listens carefully" to what the system says. In many cases, however, the listening becomes particularly intense, concentrated, deeply intimate, and during these moments she is motivated intrinsically by the very act of listening, irrespective of all else (see Fig. 12).

Figure 12. Expression of autotelic listening.

Ecstatic pleasure (Fig. 13). At other times her listening gives rise to moments of sheer ecstasy, sudden outbursts of joy. Another child, Alberto, listens to the system and exclaims: "E' bellissimo !" ("It's wonderful").

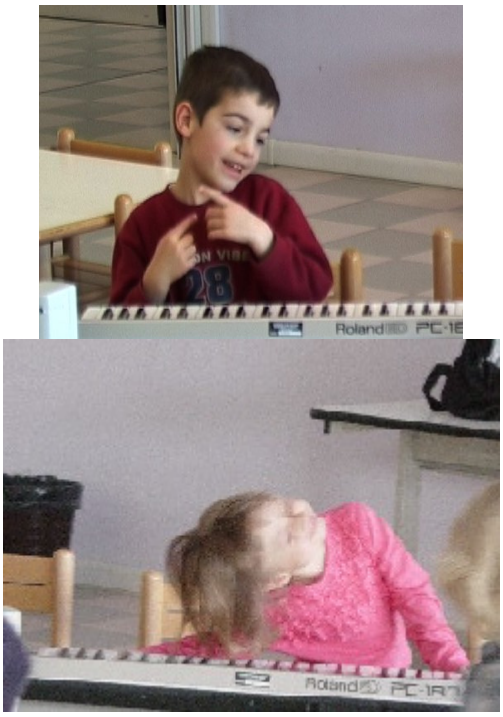

Figure 13. Various expressions of ecstatic listening.

From listening to the Continuator to listening to her/his own work (Fig.14). Another important aspect is the quality of R.'s listening to her own productions, in this case heightened by the interactive game, which encourages the child to listen carefully and compare her own pieces with the replies of the system, to identify repetitions and differences. As has often been stated, encouraging students to listen to their own musical productions is one of the main objectives of music education (Delalande, 1993a; Frapat, 1994).

Figure 14. Attentive listening to her own work.

Inventing stories. Sometimes they listen and pretend to be reading a story book, making up stories as they listen: the music of

the Continuator provides a background for their story. For example, R. uses the system as an accompaniment: when it stops playing, she calls it back by playing a couple of notes on the keyboard (Fig. 15). Her stories sometimes include what is going on around her, perhaps the words of someone who happens to be in the room at the time: a teacher asks if anyone wants a coffee, and the story suddenly involves undefined characters who are drinking coffee…. She is aware of the sounds that surround her, but at the same time she is completely engrossed in her reading and isolation. The symbolic game and the listening become an "expressive activity" as described by Baroni (1997).

Figure 15. Inventing stories.

Discussion

We shall now underline the significant aspects of these two cases, interpreting them on the basis of certain theories on creativity and musical development in children.

The nature of interaction

When observing the children interacting with the system one has the impression that they have taken on music as a partner, someone with whom she/he can share every type of experience, with whom she/he can play and work using body and mind. Their listening seems to stem from a desire to converse and interact with the other being, to understand and respond. In many ways the listening is guided by the invention of the other (What is it saying to me?) and the invention of her self (What shall I say?)

Furthermore, the system is a machine that casts no judgement and expects nothing of the performer. Therefore, unlike other machines that "have no self" and "have no other" (Baudrillard, 1990), it returns and reflects the musical style of whoever is playing (and thus has "an other"). A sort of sound mirror, similar to the relationship between mother and child observed by different researchers (see Lacan, 1974; Anzieu, 1976; Stern, 1977; Imberty 2002), but involving a more mechanical and computational approach (a Second Self, as described by Turkle, 1984).

In fact, the Continuator stimulates the children to adopt conducts that are very similar to those of 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 organize their musical discourse, passing, as in the case of T., 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 Daniel Stern (1977) in the vocal relationship between mother and child, and by Michel Imberty (2002) in the field of music. To define this phenomenon they use the term "affective syntonization".

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 year old, in Mazzoli 2001).

Styles of interaction. In case-study n. 1, G. proceeds systematically trying to understand the system: he observes it, and observes the reactions of the other children when interacting with the system. He behaves like an observer introducing variables and trying to understand the results. His relationship with the system is "symmetric" (Fogel 2000): alternation of question and answer between

two "frontal" interlocutors. He has also made contact with the system, waits for it, and when the reply does not arrive he is disappointed. He is displaying a form of *attachment* (Holmes 1994). In case 2 we see that the child passes from turn-taking, which is the basic playing mode of the Continuator, to role-taking, a term used to imply the ability to consider the point of view of the other (Emiliani & Carugati 1985).

These aspects show how, 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 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".

The rules of the system. The children learn the rules of the system:

- it replies by playing alone,
- it replies when you stop playing (turn-taking),
- repeating what you play, repeating with variations,
- it is capable of establishing a dialogue made up of repetition/variation,
- it does not always respect the rules (assessment).

During this process the children pass onto role-taking, and react if the system does not respect the rules. They also learn that they can teach the system, and the rules of the system can be taught to others; they learn to "relaunch" new rules and the "error" of the system like a new musical proposal.

Musical improvisations

We have seen, especially in case case-study 2, a transition from *exploration* (of the instrument, of the sounds, of the rules of the system) to the *invention* of music (actual improvisation, musical creation for its own sake). It is important to analyse from a musical point of view the processes called into play for this transitional passage and the way the system intervenes, as well as the musical skills developed by the children. Both in the exploration and in the improvisations, we can see personal styles in the ways of producing sounds, in the rhythmic and melodic patterns that each child prefers, in the construction of longer sequences. The Continuator, by means of its replication musical style, reinforces these individual styles, and allows them to develop and evolve. The most interesting aspect is that the invention is not individual but collective: the child is playing along with the machine, in a pair, like two musicians improvising together.

Rock or classical: the stylistic competences. The way the children play also reflects their musical background: T. plays standing up, moving a lot, his sleeves pulled down over his hands, often pressing them down on the keyboard, displaying an intense physical relationship with the instrument; G. always plays seated, composed and he draws pictures of traditional instruments, with the notes on the staff. The questionnaires of their parents tell us that T.'s father is an expert in rock music, whereas G. listens to classical music. Previous researches about the development of musical stylistic competence in children, found that young children are able to recognize musical styles, above all in the familiar repertoire (Addessi, Baroni, Luzzi, Tafuri 1995-1996; Hargreaves & North 1999; Marshall 2001): by reproducing musical style the Continuator allows us to study the stylistic competence of very young children, both as listeners and music-makers.

Theory of Flow and creativity

The data analysed until now would suggest that the Continuator, as well as similar interactive reflective systems, is able to develop creative music behaviours in young children. It is possible to recognise the conditions of creativity described in the Theory of Flow by Csikszentmihalyi (1996, pp. 111-113): 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, a balance between challenges and skills is achieved. R.'s behaviour offers many examples of the typical traits of creative personalities and creative thought: fluency in

the wide range of modes of listening, flexibility in passing from one expressive mode to another, originality in the uniqueness of some aspects of her behaviour (Vigotsky, 1973); the alternation between imagination and fantasy on the one hand and a strong sense of reality on the other; she is at the same time shrewd and yet naive, abounding in physical energy, but also quiet and restful, harbouring opposite tendencies in the balance between extroversion and introversion (Csikszentmihalyi, 1996).

Interactive reflective musical system. Because it is able to learn and imitate the user's personality, the Continuator acts as a sort of dynamic mirror, and we claim that most of the interesting properties studied in our experiments probably come from this particular characteristic. As such, the Continuator is only one instance of a larger class of system that could be called "reflective", i.e. 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. The experience of playing with a IRMS can lead to Flow states which eventually may trigger creative behaviors or creative productions. (Pachet in print).

Intrinsic motivation. The data regarding attention span, the autotelic listening, and the phenomena such as Surprise, the Aha Effect, and Excitement observed during the experiment, could be interpreted as signs of an *intrinsic motivation* that stimulated the children's interest and pleasure in using the machine and its musical and interactive games. The source of this intrinsic motivation can be traced to the ability of the system to replicate the musical style of whoever is playing the keyboard. 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 normally offer very little attraction to such young children.

Child and computer

It was particularly interesting to observe the relationship that the children established with the system from a "technological" point of view. They knew that the system worked through a computer connected to a keyboard, and they systematically tried to interact directly with the "commands" of the system and thus with the computer situated near the keyboard. They also expressed their interest in the "scientific" aspects of the phenomenon, especially in the tasks in pairs, by giving explanations about how the replies were "reproduced", or about the production of the sound ("the sounds come out of the keyboard through the wires"). This aspect poses a further question about just how independent the children can be when using musical machines. Very often the presence of an adult is indispensable. The system in question requires the collaboration of an adult only to set up the activity, after which the child can be left almost totally alone. A different kind of interface could, in fact, also allow the child to decide exactly when to play with the system, or to change other parameters such as the length of the reply or the type of turn-taking.

We observed two different learning styles: "linear" and "by immersion". The former would be more typical of the "technologies" associated with writing, such as books, while the latter is more linked to multimedia technologies (Maragliano 1999).

While playing with the machine the children display a considerable amount of *autonomy*: they manage to master the rules of the game and to control the interaction with the system. In this way there is always room for moments of subjective intuition. It is they who decide when to stop the interaction, to "break the toy". At the same time they show strong intrinsic motivation for the musical game as well as a good capacity for "distance". The "distance factor" is common to both the aesthetic and educational experience and, according to Bertolini & Dallari (2004), needs to be safeguarded even when the educational operation takes place through technological teaching tools or the mass media.

What can a teacher learn from the Continuator ?

The relation between new technologies and the development of intelligence and creativity is an area of research still full of surprises, not only regarding the birth of new forms of knowledge and new "brainframes" (De

Kerckhove, 1993), but also on account of what humans can learn about themselves by observing the behaviour of machines.

The "teaching method" of the system is based on its mirror effect and the implicit turn-taking. The most interesting aspect is that the musical invention is not individual but collective: the child is playing along with the machine, in a pair, like two musicians improvising together. It is the system that teaches the child to play with it, by guiding him from exploration towards musical invention, just like a real teacher.

So, in the realm of developing creativity, *what can a teacher learn from the Continuator ?* For instance, to respect turn-taking, similarly to when a song is taught through imitation: when the teacher sings, the children listen; when the children repeat, the teacher listens. And to act like a mirror, as suggested by the children when they say: "Teacher, look at me". Try to let the aims establish themselves during the course of the lesson; foster the pleasure of not knowing what will happen, the joy of discovery, of curiosity.

Conclusion

The results seem to suggest that the Continuator, or other similar interactive systems, is able to develop interesting child/computer interaction and creative music conducts in young children, thanks above all to its ability to replicate the musical style of the child that is playing. In this paper we have shown some examples of the life cycle of interaction, the attention span and some interesting listening conducts observed in a classroom setting. We have discussed how the data underlying theories of creativity and of the musical development of children provide some important categories for the observation and interpretation of data that make it possible to formulate various hypotheses about the nature of the interaction between children and interactive systems.

One of the most interesting results concerns the efficiency of the concept of an interactive reflective musical system. The moments of greatest concentration, pleasure, intrinsic motivation and learning seem to depend on the mechanism of repetition/variation, and thus on the "reflective" attitude of the system.

The results also highlight certain more general aspects concerning the interaction of children with musical machines, the so-called new "cognitive frames" that evolve as a result of their ever increasing contact with new technologies, new musical instruments and products of artificial intelligence in general.

We are now preparing an observation grid to analyse systematically all the children that took part in the protocol, and to check the categories established so far, as well as the influence of age. We are analysing in detail the musical improvisations produced by the children and the Continuator, and we are checking all the psychological states described by the Theory of Flow (Csikszentmihalyi 1990).

In light of these results, the project foresees the experimentation of new variants of interactive reflective musical systems, focusing on aspects other than turn-taking based on question/answer: the possibility of playing music at the same time, the development of a kind of interaction that would develop the musical ear of the children and the musical memory, and that would allow the children to create more structural musical rules.

Acknowledgements
We would like to thank the director, the teachers, the children and their parents, of the Scuola Materna Statale "La Mela" (Bologna, Italy); Simona Carlotti, Laura Ferrari and Nicoletta Rossi for their help in realising the protocol; Fabio Regazzi from University of Bologna for technological assistance.

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[1] More sophisticated examples of music created by the Continuator can be found on the web site www.csl.sony.fr/~pachet.

[2] We used the term "conduct" in accordance with the French term "conduite" used and scientifically defined by Pierre Janet, Jean Claparède and Jean Piaget. In the musical field this concept has been used by Delalande (1993b).