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Young children confronting the Continuator, an interactive reflective musical system

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• **ABSTRACT**

Background in music education. The present study deals with various the interaction between children and musical machines. One of the principal aims is to understand how the use of *interactive musical systems* can affect the learning and the musical creativity of children and more especially of younger children (3 to 5 years old).

Background in artificial intelligence. An innovative system was conceived at the Sony CSL in Paris which is able to produce music in the same style as the person playing the keyboard. The name chosen for this machine is the Continuator. Its basic design is that of *Interactive Reflective systems* where the core concept is to teach musical processes indirectly by putting the user in a situation where learning takes place through the *actual interaction* between the user and the system.

Aims. The aim of the study is to understand in what way the children relate to this particular interactive musical system, what kinds of musical and relational behaviours are developed, and how interactive reflective systems can be used in the educational field to stimulate creativity and the pleasure of playing.

Method. The study involved 27 children aged 3 to 5 years, in a kindergarten in Bologna (Italy). Three sessions were held once a day for 3 consecutive days. In every session, the children were asked to play on the keyboard in 4 different situations: with the keyboard alone, with the keyboard connected to the Continuator, with another child, and with another child and the Continuator.

Results. The present paper reports the observation of three particular aspects: the emergence of a *life cycle of interaction*, moving from initial surprise, to phases featuring excitement, analytical behaviour and invention; the fact that the two tasks involving the system gave rise to the longest *attention span* characterized by strong *intrinsic motivation* and *joint attention*; the varied nature of the *listening behaviours*.

Conclusion. The results show how an *interactive reflective system* such as the Continuator can develop interesting child/computer interaction and promote creative musical behaviours in young children. This outcome points to the considerable potential offered by the association between the disciplines of music education and artificial intelligence.

Background in music education

The relationship between new technology and learning has been studied from different points of view: the learning content and concepts particular to a subject area, or programs for creating hypermedia based on images, animations, music, vocal and other sounds which aid the listener in learning concepts through games (Webster, 2002). Most studies have dealt with children of 8 years and older and regard the didactic use of new technologies, or technologies that serve as "transparent" instruments that allow for the making and producing of music, even without attending specific courses of music composition (Folkestad *et al.*, 1998; Seddon and O'Neill, 2003). 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 Dossiers de l'Ingénierie Éducative, 43*, 2002).

Children and musical machines

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, 1991; Turkle, 1984). Music education is no exception. New technologies are creating new ways of listening as well as "new environments" in which children can develop the processes of music learning and perception, characterized more and more by the "presence" of TV, play-stations, the internet, and still today by radio and movies (Mazzoli, 2001; J. Kenway and Bullen, 2004). New technologies in the field of music education should therefore be considered 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 under-studied, that of *interactive musical systems.* Recent experiments have been carried out concerning 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 and Coglio, 1998; see also GRM 2000, MusicLab 2002, Resnick *et al.*, 1996). However, few studies have considered the "nature" of the interaction between children and musical machines.

In our study, we chose to study young children, 3 to 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. According to some developmental theories (Fogel, 2000; Stern, 1985; Trevarthen, 2002), 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 (1985), describes the musical development of a child as based on the mechanism of repetition and variation. The problem is therefore to identify 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.

Background in artificial intelligence

The Continuator is a system elaborated at the SONY-CSL in Paris, which is able to produce music in the same style as a human playing the keyboard, like a sort of sound mirror (Pachet, 2003, 2006). It is based on the notion of *Interactive Reflective systems*. The core concept of this approach is to teach musical processes indirectly by putting the user in a situation where these processes are enacted not by the user, nor by the machine, but by the actual interaction between user and system.

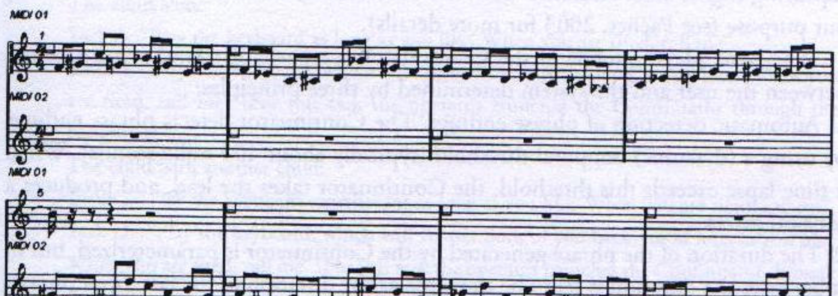

Figure 1. A jazzy line (top) is continued by the Continuator (bottom).

The main focus of the Continuator project was initially to design a system for adults, either beginners or professionals. We decided to experiment it with the children.

To illustrate the working of the Continuator, a simple musical example is given below (See Figure 1). 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.[1]

The current architecture of the Continuator consists of one MIDI input (typically from a synthesizer) and one MIDI output (typically returning to the same synthesizer). Although there is a graphical interface to tune the many system parameters, its operation in the standard mode involves no interface other than the MIDI instrument itself. The user plays musical sequences of any kind. When the

(1) More sophisticated examples of music created by the Continator can be found on the web site www.csl.sony.fr/~pachet.

phrase is terminated, the Continuator, in turn, generates a musical phrase in response. This musical phrase has the characteristic of being stylistically similar to the phrases played by the user so far. Technically, it is a continuation of the last input phrase, hence the name of the system.

The Continuator is based on a Markov model of musical phrases, and the model of the style created by the system retains melodic patterns, harmonic progressions, dynamics and to a lesser extent rhythmic patterns of the corpus used for learning. An important consequence of this approach is that the phrases generated by the Continuator are similar but different from the phrases played by the user. This notion of similarity is of course crucial in music, both from an analytical and perceptive viewpoint (most music analysis methods are based on some similarity principle (see, *e.g.* Deliège, 2001). The Continuator may therefore be seen as an engine for producing variations of arbitrary musical material. 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 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 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 the 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.

METHOD

An experimental protocol was established to observe systematically some interesting conducts[2] observed in the preliminary experience in Paris (Pachet and Addessi,

(2) We use the term "conduct" in the sense of the French term "conduite" (German: "Betragen"), as used and defined by Pierre Janet, Jean Claparède and Jean Piaget. The term appears above all in the literature of countries with Latin-based languages and is often used as a synonym 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, p. 214). Piaget defines conducts as the "behaviours including the

2004). The experiment was based on observation methodology (Mantovani, 1998). The aim was to observe the nature of interaction between the children and the machine and the musical conducts of the children, according to the exposure to the experience (3 sessions in 3 consecutives days), the age of the children (3-5), and if they play with or without the system, alone or with another child.

• **Procedure.** The experiment was carried out in an kindergarten in Bologna (Italy). Three sessions were held once a day for 3 consecutive days. In every session, the children were asked to play on the keyboard in 4 different situations: with the keyboard alone, with the keyboard connected to the Continuator, with another child, and with another child and the Continuator. The tasks were given in random order and all sessions were recorded on video. 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).

• **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 (1 girl, 2 boys). The other children either 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 care was taken not to diverge from their normal daily routine.

• **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.

• **Data analysis.** A series of key elements were identified regarding the child/Continuator interaction, independently of the scansion of the three sessions

conscience" (Piaget and Inhelder, It., 1970, p. 7). In the musical field this concept has been used by Delalande (1993).

(listening and aesthetical experience, ways of playing, exploring the instrument, joint attention, musical improvisation, pair interaction). Two case-studies were observed and analysed over the three sessions. The most interesting conducts were selected to be tested also on the other children, in order to analyse the progressive development of these conducts (the "life cycle" of interaction). The duration of each task was measured to assess whether playing with the system or playing in pairs, affected the attention spans. Finally, an observation grid was designed to analyse the Flow state.

RESULTS

Partial results of the project have already been published elsewhere (Addessi and Pachet, 2005; Pachet and Addessi, 2004). In this paper we focus on the data concerning the life cycle of interaction, an example of microanalysis, the listening conducts and the attention span.

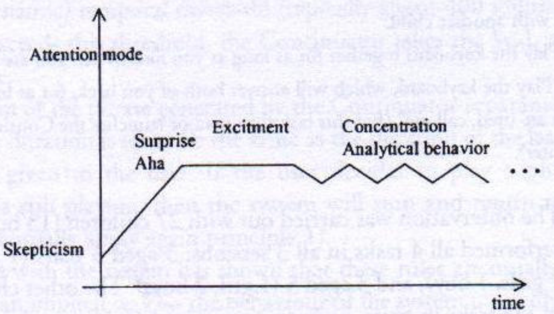

Figure 2. A tentative sketch of the "life cycle" of the interaction mode with the Continuator.

THE LIFE CYCLE OF INTERACTION

Following the first observation of the video recording, it was possible to observe an initial dynamic curve moving from *Surprise* (the *Aha Effect*), to a phase of *Excitement*, followed by a period of *Concentration and analytical behaviour*. We called this phenomenon the "life cycle" of interaction (see Figure 2). Successively, two case studies were analysed and we observed an interaction between the children and the system that builds up over time, passing through various dynamic states. We were then able to build the key moments of the life cycle of interaction between child and machine.

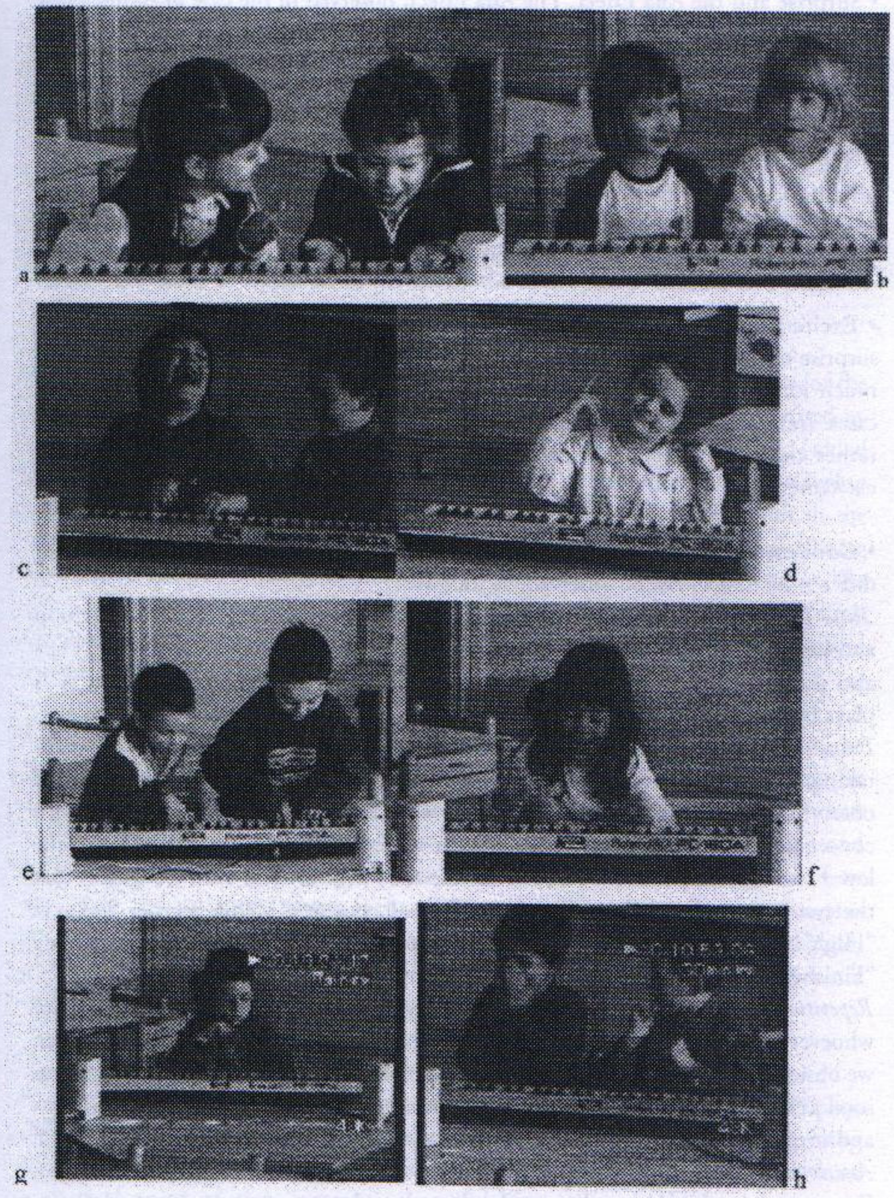

Figure 3.
Various expressions of the life cycle of interaction: a/b) Surprise or Aha Effect; c/f) Musical excitement; g) Concentration and analytical behavior; h) The child "observer": he observes the surprise of his friend on hearing the reply of the Continuator.

• **Surprise and the Aha Effect.** The Aha Effect, observed in the case of professional musicians, 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 (see Figure 3a/b).

• **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 20 minutes or more. Excitement was observed in most cases. Interestingly, the children were excited more by what the system was playing, rather than what they were doing. Figure 3c/f shows some expressions of this excitement.

• **Concentration and analytical behaviour** (Figure 3g). In this phase a series of different conducts can be observed, as follows:
Turn-Taking. The children learn the implicit rule of turn-taking. They always stop and listen to the system's reply, respecting the "turn-taking" with the system. They also teach their partner the rules of system and turn-taking: "Suona da sola" ("It plays by itself").
From turn-taking to role-taking. Sometimes we observed a transition from turn-taking, to role-taking (*i.e.* the ability to consider the point of view of the Other). We observed an example of this phenomenon in case-study n. 2: Tom 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. Tom 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". He plays his own note as played by 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 system's reply, and tries to answer in the same way: by repeating and varying what he has just heard.
Assessment of the system. The children react if the system does not respect the rules. For example: a child shows disappointment when the system plays a musical phrase longer than expected (Fig. 5d).

• **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* (Stern, 1985), 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 some repeated notes played by the Continuator because of a block of the machine.

• **From exploration to invention.** We observed a transition from *exploration* (of the instrument, of the sounds, of the rules of the system) which were characterised by the introduction of new and different elements, to the *invention* of music (actual improvisation, musical creation for its own sake), where the children develop the musical ideas (Delalande, 1993; Kratus, 1995; Mialaret, 1997). Both in the exploration and in the invention, 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.

• **Attunement.** In the case-study n. 2, when the child plays with the system, he begins playing energetically, the Continuator relaunches softly and delicately, the child 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 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. To define this phenomenon they use the term "affect attunement".

An example of microanalysis: The sense of form

During their interaction with the system the children establish a dialogue (I play, then stop, I listen to what it tells me, then I reply, and so on), where the mirroring effect plays a fundamental role both in holding the interest of the child, and, from a musical point of view, promoting careful listening and the development of musical ideas, which will often take on the form of genuine musical phrases. An example of this process is shown in the following microanalysis.

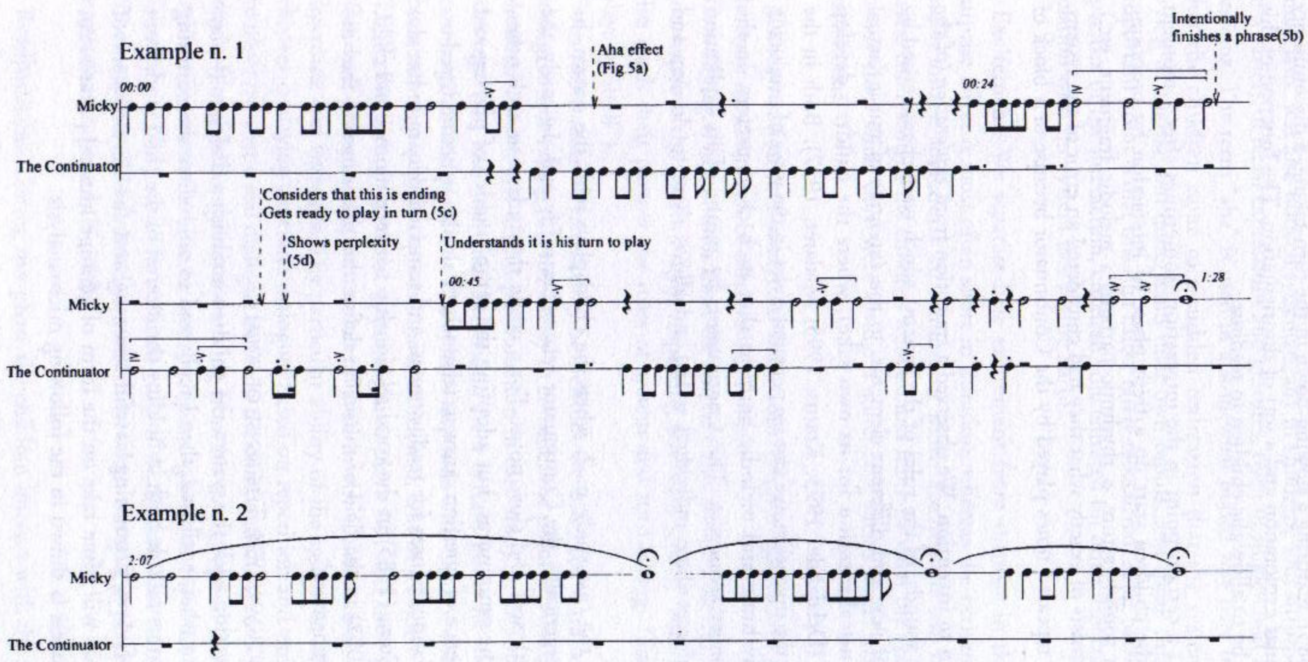

Figure 4.
Micky, Session 1, Task B. Rhythmic score: they play clusters and few short notes. Example n.1, time 00:00-1:28; Example n. 2, time 02:07-2:35.

• **Micky, 4 years old. Session 1.** Micky starts with task C (with a partner, without the system). Micky and his friend play various musical ideas, in an exploratory way. But the level of attention is low and ambiguous: the Micky's interest is divided between his friend and the keyboard. He tries to play something. Two different rhythmic patterns emerge but they remain at an explorative level; they are played and then abandoned.
This is followed by task B, where Micky plays alone with the system:

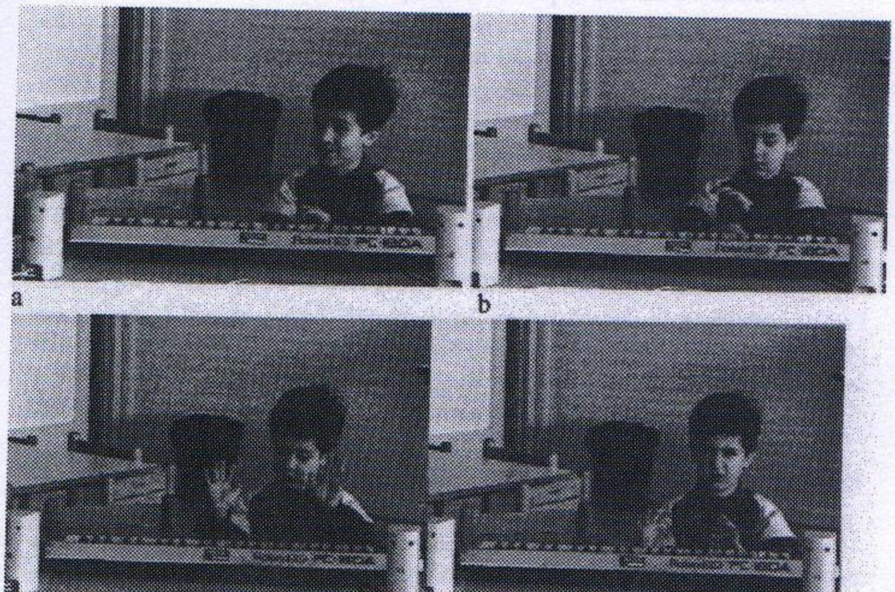

Figure 5a/d.
Micky, Session I, Task B. Short example demonstrating the complexity of the interpretation of phrase endings: a) the echo response of the Continuator elicits in Micky a pleasant sense of surprise; b) then the child plays: he intentionally finishes the phrase, and waits for an answer; c) the answer generated by the Continuator includes the last part of the input phrase. At the end of the system's (repeated) last part, the child gets ready to play again, assuming that the phrase played by the Continuator has finished; d) but it has not: the system plays some extra material, and the child shows his misunderstanding with a typical face.

Task B. Description:
- Time: 0:00-0:23 (Figure 4, example n. 1). Micky returns to the rhythmic pattern made up of two crotchets and one quaver. The immediate echo response of the Continuator, which repeats the same pattern with a small variation, elicits in Micky a pleasant sense of surprise and attraction (Figure 5a). There then begins a close dialogue that will lead,

through repetitions and variations, to an elaboration of this original musical idea, transforming it in an organic and formally structured manner.

- Time: 0:24-0:44 (Figure 4, example n. 1). Micky starts playing again with a phrase consisting of a faster initial section and a final part where the rhythmic pattern appears again, this time with augmented durations. At this point we can clearly observe the child's interpretation of phrase endings coming from the Continuator. The child intentionally finishes the phrase, and waits for an answer (Figure 5b). The answer generated by the Continuator includes the last part of the input phrase, followed by some extra material. At the end of the system's (repeated) last part, the child gets ready to play again, assuming that the phrase played by the Continuator has finished (Figure 5c). But it has not, and the child shows his misunderstanding with a typical face (Figure 5d). The Continuator then ends its phrase.

- Time: 0:45-1:28 (Figure 4, example n. 1). Once the Continuator has finished its response, Micky waits for several seconds and then begins a new and intense dialogue, during which he seems to be trying to make the system understand that there is a particular signal indicating the end of each player's turn that should be respected. The phrases actually become much shorter, consisting solely of the repetition of the previous pattern, which now becomes increasingly augmented. This goes on until it is finally taken up again with features typical of a finale: repetition, augmentation of durations, dynamic crescendo. The Continuator replies with the same cell and we then witness a sort of "attunement" between the two participants (see also the "attunement sequence" in Addessi and Pachet, 2005).

- Time: 1:29-6:27(end). From this moment on Micky's input becomes longer and more elaborate, as do the replies of the system. In this phase he manages to construct his longest and most complex phrases, made up of shorter sub-phrases that can be distinguished by the way they end with a closing variant of the rhythmic pattern (see Figure 4, example n. 2). Therefore, once the "formal" rule has been invented, "taught" and used to indicate the conclusion of each player's turn, Micky uses it, in a extension way, also to give a form to his own improvisations. The dialogue continues, including moments involving the whole keyboard and glissandos. This goes on until, at a certain point, it is the system that now returns to the original rhythmic pattern in a way that, by chance, seems to mark a sort of Recapitulation. Micky replies with the same pattern. The Continuator introduces a totally new rhythmic pattern (a dotted and irregular rhythm), Micky says "I've finished".

This example highlights how the dialogue with the system gave birth to the formal elaboration of a rhythmic pattern invented, repeated and varied, through accumulation and/or augmentation, which took on different forms and meanings during the course of the dialogue. The pattern could be said to have acquired the role of a perceptual "cue" (Deliège, 2001) used for shaping the overall "macroform" of the improvisation. We can therefore observe how the dialogue with the system helped to generate a sense of form and thus of time organization, which is evident both at a microstructural level, as well as in the medium- and macroform. Many scholars, and in particular Imberty (2002, 2005), consider time and its organization as one of the fundamental elements of musical communication, whose rules are learnt as early as the first months of life during the adult/child relationship. In this sense, from a pedagogic point of view, the machine works in terms of modeling and scaffolding (Vigotsky), by interacting with the child and "adapting" to his cognitive (and musical) capacity to organize time: the learning could thus be defined as learner-centred. We believe that this factor is one of the main reasons behind the interesting results obtained.

Listening conducts

The listening behaviour was 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 behaviour of a 4-year-old girl, R., bearing in mind that similar behaviours 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 Figure 6a).

• **Ecstatic pleasure** (Figure 6b). At other times her listening gives rise to moments of sheer ecstasy, sudden outbursts of joy.

• **From the Continuator to her/his own work** (Figure 6c). 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, 1993; Frapat, 1994)

• **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 (Figure 6d). The symbolic game and the listening become an "expressive activity" as described by Baroni (1997) .

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 (Vygotsky, 1973). We notice here that listening to music is a real act of creation (Kratus, 2004).

Figure 6a/d.

Various expressions of listening: a) autotelic listening; b) ecstatic pleasure; c) from the Continuator to her/his own work; d) Inventing stories.

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. 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 Figure 7, tasks B and D (*i.e.* those involving the system) produced the longest mean times of attention.

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 shows no significant effect on the interaction between the factors Session and Task, and nor was any significant effect found for the factor Session.

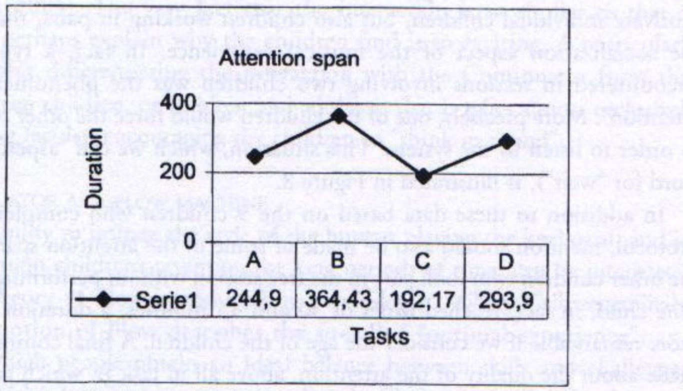

Figure 7.Attention span. Mean values for the four tasks in the three sessions taken as a whole.

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.

Figure 8.
Joint Attention. "Aspetta" ("Wait" in Italian): when one child forces the other to stop in order to listen to the machine.

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 8.

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.

Discussion

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

Styles 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 Continuator 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, 1985; Imberty, 2002), but involving a more mechanical and computational approach (a "Second Self", as described by Turkle, 1984). This phenomenon seems to stem from the system's ability to replicate the musical style of the children. The *interaction based on repetition/variation* allows the children to organize their musical discourse, passing from exploration to genuine musical invention (Delalande, 1993; Kratus ,1994). Recent studies dealing with musical invention in very young children (2-4 years) also have suggested that the origin of new musical ideas is structurally anchored on the development of the sympathetic interaction established between the adult and child and among children while playing with educational musical instruments (Young, 2004; Burnard, 2002; Miell and Littleton, 2004). The very fact that the interaction is so similar to that of humans may perhaps explain why the children find it so exciting. A particularly significant aspect differentiating the interaction with the Continuator from that observed between children, or children and adults, is that it relies almost exclusively on the listening faculty, encouraging the children to "think in sound".

THE CONTINUATOR AS A FLOW MACHINE

The system's ability to imitate the style of the human playing the keyboard, and its ability to maintain children's attention for long periods of time, can be interpreted through the theory of Flow introduced by psychologist Mihaly Csikszentmihalyi (1996). The notion of Flow describes the so-called "optimal experience", as a situation in which people obtain an ideal balance between skills and challenges. Other states can be described in such terms, but the Flow experience is fundamental in the development of creativity. The Continuator could be thought of as a Flow machine, in that it produces a response corresponding to the skill level of the user. This approach also allows for the progressive scaffolding of complexity in the interaction, which is not the case for most pedagogical tools designed with a fixed pedagogical goal in mind (Pachet, 2006). The indicators of flow experience described by Csikszentmihalyi can be discussed in light of the experiments conducted:

- *Focused attention.* The experiments show clearly that children are engaged in focused activity both when both playing and listening.
- *Ease of concentration.* This is particularly clear given the fact that no instruction is given to the children whatsoever. They play with the system in a self-motivated way, without any external constraints.
- *Clear-cut feedback.* The Continuator produces clear feedback (in fact this is the only thing it does). The interaction in some sense is reduced to the analysis of the feedback produced by the machine.
- *Control of the situation.* The children are in control of the situation most of the time. They understand quickly that they can interrupt the system whenever they want. The limitations in control are due to the difficulties that may arise when interpreting some of the system's outputs (see example in the next section).
- *Intrinsic motivation.* The most striking result of the experiments (attention span, autotelic listening, Aha Effect) is related to the intrinsic motivation of the children. 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 (O'Neill and McPherson, 2002).
- *Excitement.* Excitement is clearly shown most of the time, in particular in the early phases of the sessions.
- *Change in the perception of time and speed.* As the results on attention span showed, for most of the children time passed very quickly.

- *Clear goals.* No goal was given explicitly to the children except to play until they were bored. Indeed, improvisation is generally not goal-oriented. It could be argued, however, that the children did create spontaneously goals during their interaction. For instance, several sessions involved children trying to push the system to replicate a particular frantic musical style that they had played some minutes ago.

We made a systematic observation of flow using an observation grid, and found that the percentage when the Flow state was present is higher in task B, with the Continuator (54%) than in task A, without the Continuator (42%) (for more details see Carlotti *et al.*, 2004).

We also noticed the presence of the *flow indicators* as observed by Custodero (2005) in musical experiences:

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

Our analysis highlighted some problems in reaching flow during the tasks in pairs. This result seems similar to those obtained by Custodero. She found that child-parent pairs were either helpful or not, depending on what the parents did to either support or intervene (see also O'Neill, 1999). Consequently, we are now carrying out a specific research looking at flow in pairs.

WHAT CAN A TEACHER LEARN FROM THE CONTINUATOR ?

The "teaching method" of the Continuator is based on its mirror effect, and the strategies of turn-taking, modelling and scaffolding. 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, just like a real teacher. This aspect is very important. In fact, as the history of western music tells us, teachers lost the ability to teach improvisation during the 19th century when performers stopped improvising. In the 20th century this was partly rectified by Jaques-Dalcroze and Carl Orff, and by the creative approaches to music education developed from the Sixties onwards. But the impact of these approaches on conventional music education as a whole is still poor, and this implies that is very difficult to bring improvisation back into western musical culture (McPherson, 1994; Kenny and Gellerich, 2002). In our experiment, children learn to improvise by interacting with a computer, which is necessary if their teacher cannot, or does not want to, improvise.

So what can a teacher learn from the Continuator? Among other things, to respect turn-taking, as when teaching a song through imitation: the teacher sings, the children listen; 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, to develop *autonomy*, don't make assessments; just stimulate musical communication. Concentrate on developing learner-centred teaching, using the interactive strategies of modelling and scaffolding.

Conclusion

The data would suggest that the Continuator is able to develop interesting child/computer interaction, very similar to those of humans, as observed in infant-adult communication (Stern, 1985; Imberty, 2002), but with a more mechanical and computational approach (De Kerckhove, 1991; Turkle, 1984), which would explain why the children found it so exiting. In this paper we have spoken of the life cycle of interaction, the attention span and some interesting listening behaviours 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 (Flow Theory, collaborative creativity).

From a pedagogical point of view, one of the most notable results is that this system is able both to develop very attentive listening, intrinsic motivation, and personal musical improvisation, based on the ability and musical knowledge of the children. The next step will be to analyse in detail the musical improvisations produced by the children and the Continuator.

We believe that many of the interesting properties emerging from in our experiments arise from the efficiency of the concept of an *interactive reflective musical system*: the users can play with "virtual" copies of themselves, or at least with agents who have a mimetic capacity and can evolve in an organic fashion.

Regarding interdisciplinarity

Music education and artificial intelligence are two disciplines endowed with their own epistemology (methods, contents, subjects, languages). If scholars of music education wish to understand something about the relationship between children and machines, they need to venture into the world of those who construct such machines, work on them together, watch them at work. In this sense the present project is highly interdisciplinary, since it is not simply a matter of checking whether an interactive software works or not, of using the software in a classroom context. On the contrary, it involves being able to compare the elaboration and working processes of the machine with the processes of learning and interaction typical of children, and at a more advanced level, the methods and languages of artificial intelligence with those of music education: a sort of metacognitive study, involving the comparison of two types of intelligence, human and of the machine, and two forms of knowledge, that of artificial intelligence and that of pedagogy and psychology. As far as the music education element is concerned, in addition to the results obtained so far (see also Addessi and Pachet, 2005), it has been highly illuminating to see things never seen before and to discover that this particular type of interaction and this particular system offer conditions for the development of creativity that are much closer to the learning styles of children than many commonly applied teaching theories and practices. From the point of view of artificial intelligence, the in field experiments carried out were of great benefit when it came to verifying our initial hypotheses, and developing new ones concerning the ability of artificial systems to stimulate human creativity, and more especially gave us an insight into the design of *reflexive interactive systems* (Pachet, 2006). The results also suggested some reflections on what the human can learn about themselves by observing this system, *e.g.* the method to teach music improvisation. Therefore the data allow us to understand not only some mechanisms of child/computer interaction, but rather something about the nature of human interactions. The particular modes of child /system interaction, turn-taking, repetition and variation, represent the basic element of musical communication, like we can observe in the phenomena of lallation and baby-talk for example, and also in so-called "musical universals" (B. Nettl, J. Blacking, F. Delalande).

In the light of these results, the project foresees the experimentation of new protocols for interaction and new variants of this kind of system. The aims are to establish a "spiral organization" between system design and psychological experiments, and to perform studies in different countries in order to assess the pedagogical value of these systems.[3]

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• References

Addessi, A. R., & Pachet, F. (2005). Experiment with a musical machine: Style replication in 3/5-year old children. *British Journal of Music Education, 22 (1)*, 21-46.

Anzieu, D. (1976). L'enveloppe sonore du soi. *Nouvelle Revue de Psychanalyse, 13*, 161-79.

Baroni, M. (1997). *Suoni e significati. Attività espressive nella scuola*. Torino: EDT.

Bertolini, P., & Dallari, M. (2004). A proposito di giudizio estetico e mass media. In A. R. Addessi and R. Agostini (eds), *Il giudizio estetico nell'epoca dei mass media* (pp. 93-118). Lucca: Libreria Italiana Musicale.

Baudrillard, J. (1990). *La transparence du mal*. Paris: Édition Galilée.

Burnard, P. (2002). Investigating children's meaning-making and the emergence of musical interaction in group improvisation. *British Journal of Music Education, 19(2)*, 157-72.

Camurri, A., & Coglio, A. (1998). An architecture for emotional agents. *IEEE Multimedia, 10*, 2-11.

Carlotti, S., Ferrari, L., Addessi A. R., & Pachet, F. (2004). Suonare con il Continuator è un' "esperienza ottimale"?. In M. Biasutti (ed.), *Conference Psychology and Music Education. Proceedings*. University of Padua, 29-30 November 2004. Padova, Italy (on CdRom).

Csikszentmihalyi, M. (1996). *Creativity*. New York: Harper Collins.

Custodero, L. A. (2005). Observable indicators of Flow experience: A developmental perspective on musical engagement in young children from infancy to school age. *Music Education Research, 7(2)*, 185-209.

Delalande, F. (1993). *Le condotte musicali*. Bologna: CLUEB.

Deliège, I. (2001). Introduction: Similarity Perception <-> Categorization <-> Cue Abstraction. *Music Perception, 18(3)*, 233-43.

De Kerckhove, D. (1991). *Brainframes. Technology, Mind and Business*. Utrecht: Bosch and Keuning.

GRM - Groupe de Recherche Musicale (2000). *La Musique électroacoustique*, cd-rom. Paris: INA-GRM.

Fogel, A. (2000). Oltre gli individui: un approccio storico-relazionale alla teoria e alla ricerca sulla comunicazione. In M. L. Genta (ed.), *Il rapporto madre-bambino* (pp. 123-46). Roma: Carracci.

Folkestad, G., Hargreaves D. J., & Lindström B. (1998). Compositional strategies in computer-based music-making. *British Journal of Music Education, 15(1)*, 83-97.

Frapat, M. (1994). *L'invenzione musicale nella scuola dell'infanzia*. Bergamo: Junior (Original work published 1990).

Imberty, M. (2002). Il bambino e la musica. In J.-J. Nattiez (ed.), *Enciclopedia della Musica*, vol. II, (pp. 477-95). Torino: Einaudi.

Imberty M. (2005). *La musique creuse le temps. De Wagner à Boulez : Musique, psychologie, psychanalyse*. Paris : L'Harmattan.

Kenny, B. J., & Gellerich M. (2002). Improvisation. In G. McPherson and R. Parncutt (eds), *The Science and Psychology of Music Performance. Creative Strategies for Teaching and Learning* (pp. 117-34). Oxford: Oxford University Press.

Kenway, J., & Bullen, E. (2004). *Consuming children. Education, entertainment, advertising*. Berkshire: Open University Press.

Kratus, J. (1994). The ways children compose. In H. Lees (ed.), *Musical Connections: Tradition and Change* (pp. 128-41). Proceedings of 21st ISME Conference, Florida. Aukland, NZ: The University of Auckland.

Kratus, J. (2004). Development of a measure of creative music listening. In S. D. Lipscomb *et al.* (ed.), *ICMPC8 Proceedings* (CdRom). Evanston, USA: SMPC.

Lacan J. (1974). *Scritti.* Torino: Einaudi (Original work published 1966).

Mantovani, S. (ed.) (1998), *La ricerca sul campo. I metodi qualitativi.* Milano: Mondadori.

Mazzoli, F. (2001). *C'era una volta un re, un mi, un fa...Nuovi ambienti per l'apprendimento musicale.* Torino: EDT.

McPherson, G. (1994). Improvisation: Past present and future. In H. Lees (ed.), *Musical Connections: Tradition and Change* (pp. 154-62). Proceedings of 21st ISME Conference, Tampa, Florida. Aukland, NZ: Uniprint, The University of Auckland.

Mialaret, J.-P. (1997). *Les explorations instrumentales chez les jeunes enfants.* Paris: PUF.

Miell, D., & Littleton, K. (2004). *Collaborative creativity.* London: Free Association Books.

MusicLab (2002). 6 interactive music applications for music teaching in the National Education, http://www.ircam.fr/produits/technologies/multimedia/musiclab-e.html.

O'Neill, S. A. (1999). Flow Theory and development of musical performing skills. *Bulletin of the Council for Research in Music Education, 141*, 129-34.

O'Neill S. A., & McPherson G. (2002). Motivation. In G. McPherson and R. Parncutt (eds), *The Science and Psychology of Music Performance* (pp. 31-46). Oxford: Oxford University Press.

Pachet, F. (2003). Musical interaction with style. *Journal of New Music Research, 32(3)*, 333-41.

Pachet, F. (2006). Enhancing individual creativity with interactive reflexive musical system. In I. Deliège and G. H. Wiggins (eds), *Musical Creativity: Current Research in Theory and Practice* (pp. 359-75). Hove: Psychology Press.

Pachet, F., & Addessi, A .R. (2004). Children reflect on their own playing style: Experiments with Continuator and children. *ACM Computers in Entertainment, 1(2)*, 14.

Piaget, J., & Inhelder, B (1966). *La Psychologie de l'enfant.* Paris: Presses Universitaires de France (It. trans. 1970).

Resnick *et al.* (1996). Pianos not stereos: Creating computational construction kits. *Interactions, 3(6)*, 40-50.

Seddon, F., & O'Neill, S. A. (2003). Creative thinking processes in adolescent computer-based composition. *Music Education Research, 5(2)*, 125-37.

Sundin, B., McPherson, G. E., & Folkestad, G. (eds). (1998). *Children Composing. Research in Music Education.* Malmö: Lund University.

Stern, D. (1985). *The Interpersonal World of the Infant.* New York: Basic Book.

Trevarthen, C. (2000). Musicality and the intrinsic motive pulse: Evidence from human psychobiology and infant communication. *Musicæ Scientiæ, Special Issue 1999-2000,* 155-215.

Turkle, S. (1984). *The Second self: Computers and the Human Spirit.* New York: Simon & Schuster.

Vygotsky, L. S. (1973). *Immaginazione e creatività nell'età infantile.* Roma: Editori Riuniti.

Webster, P. R. (2002). Computer-based technology and music teaching and learning. In R. Colwell and C. Richardson (eds), *The New Handbook of Research on Music Teaching and Learning* (416-39). Oxford: University Press.

Young, S. (2004). The interpersonal dimension: A potential source of musical creativity for young children. *Musicæ Scientiæ, Special Issue 2003-2004,* 175-91.

• Niños de educación infantil confrontados al "Continuator", un sistema musical interactivo-reflexivo

Antecedentes de educación musical. El presente estudio relacionado con varios aspectos de la interacción entre niños y máquinas musicales. Uno de los principales objetivos es comprender cómo el empleo de *sistemas musicales interactivos* puede afectar al aprendizaje y la creatividad musical de los niños y más especialmente a los niños de educación infantil (de entre 3 y 5 años de edad).

Antecedentes de inteligencia artificia. Un innovador sistema concebido por la Sony CSL de París, es capaz de producir música en el mismo estilo en que una persona toca un teclado. El nombre elegido para esta máquina es el "Continuator". Su diseño básico se basa en *sistemas interactivo-reflexivos*, cuyo núcleo central es enseñar procesos musicales indirectamente, poniendo al usuario en una situación donde el aprendizaje tiene lugar a través de la *interacción real* entre el usuario y el sistema.

Objetivos. El objetivo general del proyecto completo es comprender de qué forma los niños se relacionan con este particular sistema musical interactivo, qué formas de comportamientos musicales y de relación se desarrollan, y cómo los sistemas interactivo-reflexivos se pueden emplear en el campo educativo para estimular la creatividad y el placer de tocar.

Método. El estudio se realizó con 27 niños de entre 3 y 5 años de edad, en un jardín de infancia de Bolonia (Italia). Se llevaron a cabo tres sesiones una vez al día, en tres días consecutivos. En cada sesión se pidió a los niños que tocaran el teclado en cuatro situaciones diferentes: sólo con teclado, con el teclado conectado al "Continuator", con otro niño, con otro niño y el "Continuator".

Resultados. El presente trabajo recoge la observación de tres aspectos concretos: la emergencia de un *ciclo vital de interacción*, que se mueve desde la sorpresa inicial hasta fases de excitación, comportamiento analítico e invención; el hecho de que dos tareas involucradas en el sistema aumentaran el mayor *índice de atención* caracterizado por una fuerte *motivación intrínseca* y la *atención articulada*; la variada naturaleza de los *comportamientos de escucha*.

Conclusión. Los resultados muestran cómo un sistema interactivo-reflexivo tal como el "Continuator" puede desarrollar el interés de la interacción niño/ordenador y promover comportamientos musicales creativos en niños pequeños. Estos resultados apuntan el considerable potencial ofrecido por la asociación entre las disciplinas de la educación musical y la inteligencia artificial

• Bambini a confronto con un sistema musicale interattivo: il Continuator

Legami con l'educazione musicale. Il presente studio riguarda l'interazione fra bambini e macchine musicali. Uno dei principali obiettivi è di comprendere in che modo l'uso di sistemi musicali interattivi possa influenzare l'apprendimento e la creatività musicale dei bambini, ed in particolare dei più piccoli (3-5 anni).

Legami con l'intelligenza artificiale. Presso il Computer Science Laboratory – SONY di Parigi è stato ideato un sistema innovativo, il Continuator, capace di produrre musica nel medesimo stile di una persona intenta a suonare una tastiera ad esso collegata. La sua struttura fondamentale è quella di un *sistema interattivo riflessivo*, il cui funzionamento di base è quello di insegnare i procedimenti musicali in modo indiretto, mettendo cioè l'utente in una situazione in cui l'apprendimento avvenga durante l'*effettiva interazione* fra l'utente stesso e il sistema.

Obiettivi. Scopo dello studio è di comprendere in che modo i bambini si rapportano a questo particolare sistema interattivo, quali tipi di comportamenti musicali e d'interazione si sviluppano, ed in che modo si possono usare i sistemi interattivi riflessivi in ambito didattico per stimolare la creatività ed il piacere di suonare.

Metodo. Lo studio ha coinvolto 27 bambini d'età compresa fra i 3 e i 5 anni, e si è svolto in una scuola materna di Bologna (Italia). In tre giorni consecutivi, si sono tenute altrettante sessioni quotidiane di lavoro. In ciascuna di esse si è richiesto ai bambini di suonare in 4 situazioni differenti: con la sola tastiera; con la tastiera collegata al Continuator; con la sola tastiera, ma insieme ad un compagno; insieme a un compagno e con la tastiera collegata al Continuator.

Risultati. Il presente articolo riporta l'osservazione di tre aspetti particolari: la comparsa di un *ciclo vitale dell'interazione*, che muove dalla sorpresa iniziale verso fasi di eccitazione, di comportamento analitico e di invenzione; il fatto che le due situazioni che prevedevano l'uso del sistema abbiano ottenuto da parte dei bambini i maggiori *tempi di attenzione*, caratterizzati da forte *motivazione intrinseca* ed *attenzione congiunta*; la varietà delle *condotte d'ascolto*.

Conclusioni. I risultati mostrano come un *sistema interattivo riflessivo* quale il Continuator possa sviluppare interessanti interazioni fra bambino e computer, e stimolare comportamenti musicali particolarmente creativi anche nei bambini molto piccoli. I risultati evidenziano inoltre le considerevoli potenzialità offerte dall'associazione interdisciplinare fra l'educazione musicale e l'intelligenza artificiale.

• Le jeune enfant confronté au système musical réflexif et interactif "Continuator"

Contexte de pédagogie musicale. On traite ici de l'interaction entre l'enfant et les machines musicales. L'un des objectifs principaux est la compréhension du rôle que les *systèmes musicaux interactifs* peuvent jouer dans l'apprentissage et la créativité musicale chez l'enfant et, plus particulièrement, le très jeune enfant (âgé de 3 à 5 ans).

Contexte de l'intelligence artificielle. Le centre Sony CSL de Paris a conçu un système novateur, capable de produire une musique dans le style de la personne qui joue sur son clavier. Cette machine a reçu le nom de "Continuator". Son concept de base est celui des *systèmes réflexifs interactifs* qui conduisent à un enseignement indirect des processus musicaux en plaçant l'utilisateur dans une situation où l'apprentissage s'opère par le biais de l'interaction même entre l'utilisateur et le système.

Objectifs. On étudie comment l'enfant entre en relation avec ce système musical interactif particulier, quels sont les types de comportements musicaux et relationnels développés, et comment se servir des systèmes réflexifs interactifs dans la pratique pédagogique pour stimuler la créativité et le plaisir de jouer.

Méthode. L'étude porte sur 27 enfants âgés de 3 à 5 ans d'une école maternelle de Bologne (Italie). Elle comporte trois sessions, à raison d'une par jour pendant trois journées consécutives. Lors de chaque session, les enfants sont invités à jouer sur le clavier dans quatre situations : sur le clavier seul, sur le clavier connecté au "Continuator", avec un autre enfant, avec un autre enfant et le "Continuator".

Résultats. Trois aspects particuliers sont relevés : l'émergence d'un *cycle de vie de l'interaction*, évoluant de la surprise initiale vers des phases traduisant l'excitation, le comportement analytique et l'invention ; le fait que les deux tâches impliquant le système conduisent à la mobilisation attentionnelle la plus longue, laquelle se caractérise par une forte *motivation intrinsèque* doublée d'une attention ; la nature variée des *comportements d'écoute*.

Conclusion. Il ressort des résultats qu'un *système réflexif interactif* comme le "Continuator" peut développer une interaction intéressante entre l'enfant et l'ordinateur et susciter des comportements musicaux créateurs chez le jeune enfant. Ainsi se trouve souligné le potentiel offert par l'association des disciplines de la pédagogie musicale et de l'intelligence artificielle.

• Kinder und Musikmaschinen, ein interaktives und reflektives musikalisches System

Musikpädagogischer Hintergrund. Diese Untersuchung beschäftigt sich mit verschiedenen Aspekten der Interaktion zwischen Kindern und Musikmaschinen. Eines der Hauptziele besteht darin zu verstehen, wie der Gebrauch interaktiver musikalischer Systeme das Lernen und die musikalische Kreativität von Kindern, insbesondere von jungen Kindern (3 bis 5 Jahre alt) beeinflussen kann.

Hintergrund in der Forschung zur künstlichen Intelligenz. Sony CSL in Paris hat ein innovatives System entwickelt, welches Musik im gleichen Stil wie der Spieler eines Keyboards spielen kann. Diese Maschine trägt den Namen Continuator (Fortsetzer). Sein grundsätzliches Design ist das eines *interaktiven reflektiven Systems*, dessen Konzept darin besteht, dass musikalische Prozesse indirekt durch *wirkliche Interaktion* zwischen Nutzer und System gelernt werden.

Ziele. Das übergeordnete Ziel des Projekts ist zu verstehen, wie Kinder auf dieses interaktive musikalische System reagieren, welche Arten von musikalischen und anderen Verhaltensweisen sich entwickeln und wie interaktive reflektive Systeme für die Förderung von Kreativität und Spielfreude genutzt werden können.

Methode. Die Stichprobe umfasste 27 Kinder im Alter von 3 bis 5 Jahren aus einem Kindergarten in Bologna (Italien). Es wurde an drei aufeinander folgenden Tagen jeweils eine Versuchssitzung durchgeführt. In jeder Versuchssitzung wurden die Kinder angewiesen, unter vier verschiedenen Bedingungen mit dem Keyboard zu

spielen: alleine mit dem Keyboard, mit dem Keyboard in Verbindung mit dem Continuator, mit einem anderen Kind, mit einem anderen Kind und dem Continuator.

Ergebnisse. Der vorliegende Artikel beschreibt die Beobachtungen dreier spezieller Aspekte: die Entstehung eines *Lebenszyklus von Interaktionen*, der von anfänglicher Überraschung über Phasen großer Aufregung und Erkundungsverhalten zu Erfindungsreichtum führte; wurde in beiden Continuator-Bedingungen die längste *Aufmerksamkeitsspanne* beobachtet, die sich durch eine starke *intrinsische Motivation* und *Aufmerksamkeit* charakterisieren lässt; ausserdem die unterschiedlichen Formen des *Hörverhaltens*.

Schlussfolgerungen. Das Ergebnis zeigt, wie ein *interaktives reflektives System* wie der Continuator eine interessante Interaktion zwischen Kind und Computer erzeugen und kreatives musikalisches Verhalten bei jungen Kindern fördern kann. Dieses Ergebnis verweist auf ein erhebliches Potenzial dieses Forschungsdesigns, das an der Schnittstelle zwischen den Disziplinen Musikpädagogik und künstliche Intelligenz verortet werden kann.