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From Eco to the Mirror Neurons: Founding a Systematic Perspective of the Reflexive Interaction Paradigm

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ABSTRACT

The MIROR Project (EC project, FP7-ICT) deals with the development of an innovative adaptive system for children' music improvisation, composition and body performance, based on the *reflexive interaction* paradigm. This paradigm is based on the idea of letting users manipulate virtual copies of themselves, through specifically designed machine-learning software referred to as interactive reflexive musical systems (IRMS). In this paper, the theoretical framework of the reflexive interaction paradigm is discussed from a systematic musicological perspective. Implications are introduced, aiming to support the hypothesis that the *reflexive interaction* enhances teaching/learning processes and musical creativity in children.

I. INTRODUCTION

The reflexive interaction paradigm is based on the idea of letting users manipulate virtual copies of themselves, through specifically designed machine-learning software referred to as interactive reflexive musical systems (IRMS) (Pachet 2003). In this paper, the theoretical framework of the reflexive interaction paradigm is discussed from a systematic musicological perspective. It starts from the conceptual and technical background of the IRMS and will continue with a path that try to explain the human behaviours involved in the reflexive interaction. These highlighted elements will be proposed to support the hypothesis that the reflexive interaction could enhance teaching/learning processes and musical creativity in children, placing some fundamentals for a pedagogy of reflexive interaction. Research is carried out in the framework of the EU-ICT Project MIROR (Musical Interaction Relying On Reflexion).

II. FROM ECO TO THE MIRROR NEURONS

From a systematic musicological perspective, the theoretical framework of the reflexive interaction paradigm could include references from the myth of Eco (Ovidio, 43 a.C.-18, *Metamorphoseon libri XV*), to the theories of the empathetic power of music, the *Affektenlehre* (Vincenzo Galilei, *Dialogo della musica antica et della moderna*, Firenze, 1581; Athanasius Kircher, *Musurgia Universalis*, 1650), to the more recent semiological paradigmatic analysis (Meeùs 1993, Ruwet 1966, Nattiez 1986) and theories of similarity perception in listening music (I. Deliège 2003, Toiviainen 2007), playing an important role in the infant musicality development and in the ontological fundamentals of the human musicality (Trevarthen 2000, Dissanayke 2000, Imberty 2005, Mithen 2005, Cross 2008), and finally grounding its neurophisiological fundamentals on the theory of mirror neurons (Rizzolatti et al. 1998). Moreover, a concept across is included in this systematic overview on the reflexive interaction paradigm, that is the concept of style: in principle, during a reflexive interaction (RI in short) the other does not imitate exactly what the imitated is doing, but rather imitates her/his style, in our case her/his musical style. Moreover, there is another aspect that characterises the RI paradigm, namely that it involves not only human identities, but also virtual and artificial intelligence: in the MIROR platform the other that imitates your style is not your mother, nor the lover of Eco's myth, but rather a machine.

This fact leads to an other important question, that is what happens when these interactions are determined not among human (including children), but between humans and machines, and in our case, between children and machines? The problem of child/machine interaction has already been raised for many years by an important literature of scientific and theoretical studies of scholars who have examined how the interaction with the new technology can model the human everyday behaviour, intelligence, mind and body cognition (e.g. see Turkle 1984, De Kerckhove 1991, Nehaniv & Dautenhahn 2007, Godøy & Leman 2010). However, studies are still lacking on reflexive paradigm in child/machine interaction.

In 2002 it is published the first article on a system that produces real-time responses that mimic the style of a musician who plays a keyboard, a virtual alter ego with which to undertake challenging duets: the Continuator (Pachet, 2003). The idea is to develop a machine that gives to the user the perception to interact with something the same as himself. In this case the machine does not exactly mimic the user's proposal, but his musical style, or, in other words his musical identity. The experiments that followed immediately after with adults (e.g. see Pachet, 2006) and especially with children (e.g. see Addessi & Pachet, 2005) have made it immediately obvious the potential of these reflexive systems for the development of creative musical experiences. The paradigm of reflexive interaction could contribute to the field of theoretical studies on music creativity, bringing a fresh perspective in technological and pedagogical applications.

III. THE INTERACTIVE REFLEXIVE MUSICAL SYSTEMS

Interactive Reflexive Musical Systems, were originally conceived at the SONY FRANCE Computer Science Laboratory in Paris (Pachet, 2003, 2006). The notion of IRMS emerged from experiments in novel forms of man-machine interactions, in which users essentially manipulates an “image” of themselves. This idea took the form of a

concrete project dealing with musical improvisation, The Continuator. The Continuator is able to interactively learn and reproduce music of "the same style" as a human playing a keyboard, and it is perceived as a stylistic musical mirror: the musical phrases generated by the system are similar but different from those played by the users. Technically, the Continuator is based on the integration of a machine-learning component specialised in learning and producing musical streams, in an interactive system. It was the first system to propose a musical style learning algorithm in a purely interactive, real-time context. In a typical session with the Continuator, a user freely plays musical phrases with a (Midi) keyboard, and the system produces an immediate answer, increasingly close to its musical style. As the session develops, a dialogue takes place between the user and the machine, in which the user tries to "teach" the machine his/her musical language. As an example, Figure 1 shows how a simple melody is continued by the Continuator.

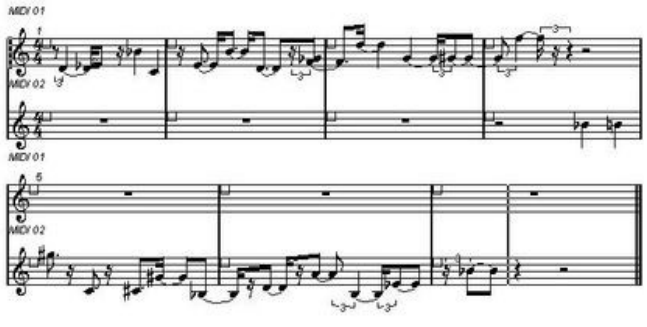

Fig. 1 A simple melody (top staff) is continued by the Continuator in the same style.

IRMS are designed without a specific task in mind, but rather as intelligent "mirrors". Interactions with the users are analysed by IRMS to build progressively a model of this user in a given domain (such as musical performance). Technically, this image is most of the time imperfect, for many reasons, including the intrinsic limitations of machine-learning systems. However, it is precisely this imperfection which produces the desired creation side-effects. Target objects (e.g., melodies) are created as a *side-effect* of this interaction, rather than as direct products of a co-design by the user. Further and more complete discussions on software and hardware background of IRMS could be found in Pachet 2003, 2006, Pachet et al. 201. In this paper it is important to point out some features of these systems that emerged as requirements of reflexive interaction, as follows:

*Agnosticity***.** The IRMS's ability to reproduce the user's personality is learned automatically and agnostically, i.e. without human intervention.

Scaffolding of complexity. Each interaction with the system contributes to changing its future behaviour. Incremental learning is a way to endow the system with an organic feel, typical of open, natural systems, as opposed to pre-programmed, closed-world systems.

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

*1) Automatic detection of phrase endings***.** The Continuator detects phrase endings by using a (dynamic) temporal threshold (typically about 400 milliseconds). When a time lapse exceeds this threshold, the Continuator takes the lead, and produces a musical phrase.

2) The duration of the phrase generated by the Continuator is parametrised, but in most cases the duration is set to be the same as the duration of the last input phrase.

3) Priority is given to the user. If the user decides to play a phrase while the Continuator is still playing, then the system will stop and return to listening mode (and eventually apply again principle 1).

IV. FOUNDING A SYSTEMATIC PERSPECTIVE OF THE REFLEXIVE INTERACTION PARADIGM

In the next paragraphs, you will be offered a path that try to explain the human behaviours involved in the reflexive interaction, starting from the observation of the interaction of children with the Continuator.

A. The mechanism of repetition/variation

One of the most interesting aspects observed in experiments with children and Continuator is exactly the nature of the interaction which is established in a RI. One innovative feature of the Continuator is the creation of a natural, organic dialogue with the child. This dialogue is based on the mechanism of *repetition and variation*, that in fact is at the heart of the reflexive interaction: the system's repetition of the input given by the child allows the child to perceive the response of the system as a sort of sound image of her/himself. And this is the moment in which the child shows an absolute attraction for this other that is similar to her/himself. The interesting thing is that it is not a merely repetition/imitation/echo, but rather a repetition always constantly varied. Now, is exactly the co-presence of something that is repeated along with something different that seems to make the RI a sort of device of attraction first, and then of stimulation of interest to get involved in the interaction. "He repeats but it is different" in this sentence that a child of 5 years expressed after hearing for the first time the response of Continuator, seems to be contained the attractive power of the RI. In Addessi & Pachet (2005), it is showed some examples of micro-analysis in which it appears this mechanism and how it develops:

4) Example 1: "After some minutes, Jerry (5 year-old) plays one note at random (G, staccato) and is about to fold his arms and listen to the machine's reply, but the Continuator plays back the same note and merely adds the octave (G3-G4). Jerry recognises his own note like in a mirror: he is surprised, looks at the keyboard, lifts his hand and then immediately replies with the same note and a variation (G-G-A-A-B-cluster). This marks the start of a real dialogue based on repetition and variation: Jerry and the system reply to each other and add variations in register, rhythm, modes of playing (e.g. Jerry plays G staccato, Continuator: G-G staccato;

Jerry: G-G-A-A-B-cluster, Continuator: cluster/rising arpeggio; Jerry: short cluster, Continuator: cluster, rising 3rd etc.). This type of interaction gives us a good idea of how the system is able to imitate and vary the child's proposals, and how this aroused in the child a sequence of emotions going from surprise and interest, to curiosity, which encouraged him to turn a random single note (G) into an alternating succession of variants of a rhythmic-melodic cell, making up an interesting, albeit brief musical dialogue.(...) when the system's replies became very varied and the mirror effects vanished, Jerry lost interest, the dialogue ceased, and he asked for the game to stop." (p. 32)

5) Example 2: "they (the child – 5 year old - and the Continuator) play short rhythmic and melodic patterns, repeat and elaborate them, then play short but complex musical phrases. At a certain point he moves towards the lower register and plays C1. The system responds with C4-A5. Tom recognises that the system has played the same note as he had but at a higher register and says "High"; he then goes to the upper register and, imitating the system better than the system had done with his proposal, plays C5, and then goes away saying "Finished". While the Continuator plays Bb-A. Tom has understood the system, has played with it, has learned to make it imitate him and to imitate the system." (p. 36)

In these examples, it is possible to observe several interesting things:

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

We find in the scientific literature several references that help us better understand the neuroscientific, psychological and social aspects of this mechanism.

B. Imitation and infant musicality

Several studies have provided evidence of the important role of the mechanism of repetition/variation in infant-adult interaction and in child musical development (Papousek 1995, Trevarthen 2000, Malloch 2000, Stern 2004, Imberty 2005, Gratier & Apter.-Danon, 2008). Between two and six months, the child is in full babbling: this phenomenon seems to be caused by the exploration of the voice (circular reaction) of the child but also by the imitation of sounds heard by adults or other children. This process of exploration/imitation, firstly random, begins to grow more and more in a context of relationship with the mother and, through the mother, in relation to her/himself. The mother's voice, with its repetitions and echoing, represents some sort of sonorous mirror for the child which reinforces her/his Musical Self. Anzieu (1996) calls this kind of infant experience 'musical wrapping' of the Self, in which the Self is described like the first embryo of the personality felt as a unit, individuality, and which express one of the more archaic shape of the repetition: the *eco*. The above scholars have observed this phenomenon in terms of interactional and inter-subjectivity, which shows that the phenomenon of imitation is mainly a bidirectional phenomenon, in which the imitation of the child by the adult plays a vital role in child development. In this field of study, research on infant musicality have emerged as increasingly important, to be offered as paradigms that characterise the human gene and human communication (e.g. see devoted symposia in ICMPC10, ICMPC11, Edinburgh 2011 conferences; see also Deliège, Vitouch, Ladinig 2010). Developmental psychologists have devoted much research to the phenomenon of imitation in childhood (for an overview see Nadel & Butterworth 1999) and the early imitation is currently a major topic of research (Nadel 2002), grounding the evolutionary and onto-genetic theories of language and human communication (Meltzoff & Prinz,2002). The majority of this research refers to the ability of children to imitate, described by Meltzoff as the *like-me mechanism*: "persons are like-me entities in so far as they can do like me, and I can do like them" (Nadel 2002, 46).

Self-imitation. The Piagetian concept of circular reaction already included the self-imitation process: in babbling for example, the child repeats their own vocal gestures, thereby developing the perception of relations between physiological sensations and the intrinsic quality of the emitted sound. Imberty (1990) assumed that in this process the child built what he called the "vocal scheme", that is an anticipation of the body scheme. According to Rochat (2002), by imitating their own action by the circular reactions, young infants gain a sense of themselves as differentiated agents in the environment; self-imitation would serve primarily an ego function and it could be said that it is at the origin of "what is arguable one of the trademarks of human cognition: the capacity for self-reflection and ability to generate thoughts that fold back upon themselves." (pp. 94-95).

6) Imitation recognition. When do children begin to recognise that the other is imitating? Nadel (2002), studies the processes of imitation recognition in early childhood and says that these processes appear first as a simple level not fully manifested until around 24 months. Nadel (2002) studied how it would develop imitation recognition ability in children, which include that the child attributes intentional imitation to the imitator. One of the first strategies of the mother to attract the attention of the children is to imitate them (Stern, 2004). Fourteen-month-old prefer an imitative adult to a non imitative adult (Meltzoff, in Meltzof & Prinz 2002). The infant is vocally more active as the parent imitates him/her (Addessi 2009). This literature show the importance of the experience of the children interacting with an IRMS, that is the perception of being imitated by someone.

7) Repetition/variation. According to M. Papousek, in the baby-talk, the language that adults use when talking to children, appears common traits that have universal basis: segmentation, repetition, syntactic simplicity, slow time, simplifying and amplification of the melodic contours. In fact, the fixity is only relative since alongside the principle of repetition that holds the baby talk, is a principle of concomitant variation that encourages the child to adaptation, constant enrichment of the basic repertoire, vocal creativity in the game. Bruner (1983) uses the term format to define the repetitive sequence of the tutoring role of the adult, which structures the spontaneous activity of the newborn child, for example, by replying to spontaneous vocalisations and creating sequences of lallation-imitation of the mother-lallation of the child. The format can be seen as early routines of exchange, which repeat themselves in terms of structure while becoming progressively richer through variations. The routines of exchange are integrated and inserted into more extensive routines related to the social and cultural habits of the group, the family and the community. M. Papousek (1995) notes that the melodic and vocal interactions between parents and children, the sequences are accompanied by gestures, bodily rhythms, movements shared by the protagonists. According to Stern (2004), more than half of the repetitions, whether vocal or verbal, involves changes. The repetition creates a pattern that allows the subject to anticipate the course of time and thus in a certain way of mastering it. This mechanism should create a sequence of tension and relaxation, generated by the repetition of elements and by the waiting for such repetitions. The sequence of interaction presents episodes of commitment, where it alternates repetitions and variations of rhythm, shape, intensity, and moments of readjustment in which the two partners found other times and then start again with a new sequence. The affect attunement is the moment of greatest trade between the two partners, in which the rhythms, shapes and the intensity of the gestures, the voice and of the gaze, are shared by both partners like in a mirror.

These factors indicate that it is only thanks to the presence of repetition that there can be a significant variation and stimulating dialogue. The excessive variation was found to induce the child to relax and produces systems of asymmetric co-regulation, if not breaking from the child (Fogel 2000). On the contrary, is exactly the fact that the repetition is imperfect that guarantees the experience of social resonance in the child. Nadel (2002) underlines that in the imitative process grounding the perception of social contingency, the children are aware that the social contingency is never perfect (p. 55). “It repeats but it is different”, a 5 year old said after listening the Continuator's reply: what happens is that during the reflexive interaction the children are pushed to manipulate their (musical) Self by the dialogue with the mother/father/adult or, in the case of the IRMS, with a machine.

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

8) Temporal contingency, Turn-taking, Regular timing turn, Role-taking.. We return to infant/adult interaction to focus on other features that accompany this type of interaction of repetition / variation and that we observed in child/Continuator interaction. They are the temporal contingency, the turn-taking, the regular timing turn, the role-taking. Many scholars agree on the fundamental importance of the temporal contingency in mother-child interaction, that is, when the time gap between the child’s signal and the adult’s reply is sufficiently short and thus considered a causal connection (e.g. Murray & Trevarthen, 1985). In presence of maternal stimulations that are *non-contingent* (i.e. the mother does not respect the timing of the interaction), lacking in emotional sharing, or are excessive and intrusive, the behaviour of the child is characterised by passiveness or disorganisation (Double Television communication set-up in Murray & Trevarthen, 1985; see also Papousek, 2007). The *turn-taking* is another feature of the interaction child/infant (at least in Western culture). One of the first forms of reciprocal sensitivity to time can be found very early on through the alternation of feeding turns (Kaye & Wells, 1980). But the turn-taking also has another function: to listen and be heard. The *regular timing turn* refers to the phenomenon of the regularity of the durations of children and adults turns, who tend to be essentially similar. Bullowa (1979) advanced this hypothesis, sustaining that in order to share meaning with the adult, rhythms must also be shared and that this sharing is at the basis of communication.

Trevarthen (2000) has hypothesised that the 'pulse' is essential in interpersonal coordination, as observed in proto-conversations (i.e. a vocal duetting of behaviour that resembles conversation between adults), between mothers and children in their first months of life. This idea was further developed by Malloch (2000), who defined this type of exchange as 'communicative musicality', a term which describes the pervasive nature of musical experience in the life of the newly born child. *Role taking:* the moment when one of the two interlocutors take the partner into account and as a consequence regulate your own behaviour according to that of the other.

It's important to emphasise that the metaphor of interaction with mother / child interaction does not mean that the child / machine and human interaction is the same thing. This metaphor helps us understand what are the interactive mechanisms that underlie human reflexive interaction with an IRMS. The IRMS generate very complex reactions, where the children are expected to form differentiated judgements about "self" and "others". In literature, these forms of awareness are considered crucial for the building of the child's identity. IRMS, by means of its mirror effect, help towards the construction of a "musical self", or, in the words of Turkle (1984), a "Second self", where not only the machine seems to think, but also think like the user.

Turn-taking, regular timing turn, role taking, temporal contingency were observed in child /IRMS interaction and we believe that is exactly the presence of these mechanisms that make so effective the RI between children and the IRMS.

9) Adaptation and co-regulation of musical dialogue. The phenomenon of adaptation in real time is one of the most complex phenomena of human behaviour, because it happens in real time, it is different every time, and it is based on a process of co-regulation between two or more partners (e.g. see the attunement concept by Stern, 2004, the inter-subjectivity by Trevarthen, 2000, the relational coding system by Fogel 2000). The IRMS are adaptive machine because they posses the ability to co-regulate their behaviour with the user in real time during the interaction. In the Example 3, you can observe an example of musical co-regulation between a 5 y.o. child and the Continuator, where the partner adapt each other in real time. In this example, we are not simply dealing with a matter of repetition/variation, but rather with a situation that is more complex on account of the dynamic, formal and temporal aspects taken into account, where musical form and emotional experience proceed in a reciprocal and parallel fashion. For this raison, we have called this phenomenon "attunement", due to certain similarities with the affect attunement described by Stern.

10) The rules of interaction become musical rules. Just as during the vocal interaction with the adult the child learns to co-construct meaning systems and to communicate, during the interaction with an IRMS the child learns to build musical phrases and to express themselves through a language of sounds. In the following example it is possible to observe that the rules governing the interaction (turn-taking, regular timing turns, imitations, variation, contrast) also become musical rules:

Example 3: "Attunement sequence": Tom, 5 year old + the Continuator. Total time: 37 seconds. The turns last around 1 second each, apart from the last ones, which take about 5 seconds each. A very short pause (less than 1 second) precedes sometimes the Tom's turn.

0.00: T: starts by playing energetically with a cluster of notes, forte (a); C: replies with a loud cluster (a'); short pause
0.03 T: repeats the cluster, forte (a")
C: so does the Continuator (a"')
0.06 T: plays a glissando, again loudly (b)
c: the Continuator plays a few notes, loudly (b')
- short pause
0.09 T: plays two glissandos simultaneously, decrescendo (b")
C: plays a short sequence of several notes, continuing the decrescendo (b"')
- short pause
0.12 T: delicately plays 1 note ppp, in the middle register (c) -
C: two notes, ppp, in the lower reg (c').
0.15 T: starts playing note clusters again, energetically, agitated, forte (a^v)
C: replies with loud clusters (a^v)
0.17 This type of exchange is repeated tree more times, increased intensity and longer duration (a+a), (a+a), (a+a)
0.26 T: the 5th time Tom's phrase is much longer and loud, then he gets up to look at the computer screen (a'+a')
(as from Addessi & Pachet 2005, p.37)

What strikes one most of all in this sequence is the regularity in the timing of each turn, and the fact that both partners follow the same dynamic pattern, first forte (A), then decrescendo and weak (B), and finally forte again, with repetition, increased intensity and longer duration (A), that giving rise to the structure of the overall *dialogue*: **A** (a+a a+a b+b' b"+b"') + **B** (c+c') + **A'** (a+a a+a a+a a+a a'+a'). From a pedagogical point of view, it can be said that the child learns to create musical sentences, or more precisely, to co-construct musical phrase together with the system. The musical phrase generated during the dialogue is not set as "goal" to achieve by the child, nor the system: it is rather the result of the interaction, an example of *side-effect*.

C. The mirror behaviour

Recent studies (Lakin et al. 2003) suggest that the mere perception of another's behaviour automatically increases the likelihood of engaging in that behaviour oneself. The capacity to replicate the behaviour of others grounds on one part on non-conscious processing known as the "chameleon effect" (Chartrand and Bargh, 1999). Neuroscientific studies root these non-conscious mechanisms in the mirror neuron system (MNS), a network of neurons which become active during the execution and observation of actions (Rizzolatti et al. 1998, 2002). A particular class of premotor neurons was discovered in the monkey premotor cortex: the mirror neurons. These neurons discharge both when the monkey performs an action and when it observes another individual making a similar action. On the basis of this discovery and further studies, the authors hypothesise that there is a very general, evolutionary ancient mechanism, named *resonance mechanism*, through which pictorial description of motor

behaviours are matched directly on the observer's motor "representations" of the same behaviours. The "resonance" is a metaphor from acoustical domain, used to describe the correspondence between observed and executed biological motions. "It is as if neurons in these motor areas start to "resonate" as soon as the appropriate visual input is presented. This "resonance" does not necessarily produce a movement or an action. It is an internal motor representation of the observed event which, subsequently, may be used for different functions, among which is imitation." (2002, p. 253). According to Rizzolatti, this mechanism is the basis of social interactions and cognition. The mirror neurons held to the motor areas of the brain. This perspective also founding the recent theoretical perspective on embodied cognition. . According to Rizzolatti, the human communication has a neurobiological basis in the action rather than in cognition.

The discovery of the mirror system has been followed by further studies that are giving the neuroscientific explication of several phenomena such as language learning synaesthesia, emotions, the expressiveness of the action. Kohler et al. have shown that listening to sounds associated with particular actions would trigger the neurons of these actions allowing the subject to represent the action associated with those sounds.

In the field of the embodied music cognition, Leman (2007), stresses that "there is evidence, (...), that mirror neurons are *amodal*, in the sense that they can encode the mirroring of multiple sensory channel" and, above all, "Mirror neurons perform sensory-motor integration and transformation as the basis of imitation" (91). Therefore, the RI would stimulate a "resonance mechanism" in the child interacting with an IRMS. This resonance would have a neural basis in the mirror neurons system. Because the mirror system is grounded on the action, subsequently, the RI would be grounded in motor areas of the brain.

What type of motor resonance is triggered, and if it is triggered, in the perception of sound variations ? It is possible to hypothesise that during the reflexive interaction the child has the possibility to build new motor patterns of musical gestures, on the basis of schemes already possessed, by trial and error. This field of study is in fact still largely unexplored. The IRMS would be a helpful tool not only to enhance the "resonance mechanism" but also to investigate them.

11) Attribution of imitating intentionality. We have observed that the child inferred an intent to response s/he received from the system: that "other" had been named "the keyboard that answers", a sort of virtual musician. This phenomenon is very intriguing. Nadel (2002) wrote that "A very simple level of imitation recognition does not imply attribution to the imitator an intention to imitate. Higher level of recognition imply such an attribution and require understanding the imitator as an intentional agent planning to imitate your behaviour. (...) we might talk of recognition of communicative imitation when the model understands the partner's imitation as caused by the intention to conform to what the model intends him/her to do." (p. 54). The importance of communicative intentionality is emphasised by many scholars, who attribute the ability to capture the intent in the first months of life (Stern 2004, Trevarthen 2000, Imberty 2009). The problem again arises when the interaction takes place between two agents, one of which is human, that has and that infers intentionality, and a another is a machine. Gergely and Watson (1999, cit. in Nadel 2002) reported and interesting finding: the two-year-olds preferred an imitative contingency of their hand movements to a perfect computer-generated contingency, while children with autism preferred the perfect contingency. Nadel (2002) says something interesting for our purposes: "healthy infants were more interested in imperfect contingency because it met their expectancies for agency. They had already formed generalised expectancies for human social behaviours which include an awareness of the fact that social contingency is never perfect (Bigelow 1999). It would not be the presence of repetition to ensure a social resonance to the imitation recognition in the child, but the fact that this repetition is imperfect. In some respects we should infer that the attribution of human intentionality to IRMS by children is even higher than other machines because the system is "imperfect", as repeats introducing continuous variations: 'It repeats . . . but isn't exactly the same', said a 5 y.o. child after listening to the Continuator's reply (Addessi & Pachet 2005).

12) Action-based approach and expressive gesture. An other perspective to investigate the intentionality attribution in the RI is based on the action-based approach, introduced in Leman (2007) in the field of embodied music cognition. According to Leman, "the essence of corporeal intentionality is the articulation of moving sonic forms, with the emphasis on movement in relation to behavioural resonances of the human body." (84). The corporeal intentionality grounds its basis in the mirror neurons system. Leman refers primarily to the fact that the mirror neurons triggered when the subject sees an action set in place with a purpose: grasping an object, for example, or walking. "If action and perception are indeed tightly coupled (probably due to overlapping neuronal codes), then it should be possible to derive action sequences from perception in order to see how intentionality is reflected in the action sequences" (84-85). Leman's perspective is particularly interesting in our context of child/machine interaction because it affirms that "If corporeal intentionality can be captured in articulations, it may provide a key to communicating with technologies that mediate access to stored, encoded, physical energies" (85). According to this perspective, children who interact with an IRMS, would perceive the imitation as a musical gesture by means the mirror neurons system, and in so doing, would perceive an intentionality in the imitator, even if machine. According to Byrne (2002), "once imitation is seen as something that can take place without prior causal/intentional understanding of what is imitated, then a predictions that sometimes the process of imitation may be helpful for acquiring such understanding. That is, an organism may imitate a complex behaviour process without understanding it, and by doing so come to grasp better the cause-and-effect nature of the process and its purpose" (135). The expressive gesture

analysis (Camurri et al. 2004) will be integrate in the MIROR platform to exploit the resonance powerful of the IRMS (see below).

D. Auditive similarity perception

Since we are talking about RI in music, it is important to question about the auditive and musical similarity perception. Deliège (2003), shows that the listeners, when faced with music that is not ruled by tonal structures, tend to identify certain qualities of sameness and difference which can easily be perceived and memorised, allowing the listener to abstract "cues" (or prominent features) which distinguish one part of the piece from another. These theories could help to understand the way children perceive and understand the mechanism of repetition/variation during the musical interaction with the system. Furthermore, it could help to implement reflexive systems more adapt to the children similarity perception. Other perspectives highlight how the human ability to perceive similarities and differences, is strictly dependent on socio-cultural factors. Other theories, stemming from embody cognition, may highlight how this perception does not belong only to the cognitive domain but also to the motor one. The discovery of mirror neuron system and the neuroscience are opening new perspectives on these basic mechanisms of human functioning, which intersect areas previously thought to be oppositional, such as that of culture and cognition. In the case-studies of the interaction between children and IRMS, in our opinion, all these perspectives should be taken into account.

E. Reflexive listening

The listening behaviour of children interacting with the Continuator was particularly rich and varied: concentrated, analytical, but also symbolic. It is very interesting the quality of the children's listening to their own productions while they played, heightened by the interactive element that encourages them to listen carefully so as to compare their own pieces with the reply and new proposal of the system, and to identify repetitions and differences. As has already been reiterated many times in the world of teaching, listening to one's own musical productions while playing is one of the main objectives of music education (Delalande 1993). It can be traced different types of listening stimulated by the RI:

Attentive and analytical listening: children listen carefully to the Continuator's answers, it seems that seek to understand the rules that govern them; *Embodied listening:* children listen to the Continuator dancing and free movements of the body interpreting the sounds heard; *Tutoring:* In sessions in pairs, usually the child who already knows the system, guides his partner; *Empathic listening:* children follow "affectionately" the musical evolution of the system and treat it like a living thing; *Joint listening:* in games in pairs or in groups, listening becomes socialised: the children share the experience through looks, words, gestures; *Ecstatic listening:* sometimes listening achieves moments of genuine ecstasy of pure aesthetic pleasure, followed by expressions of joy: "It's beautiful!"; *Autotelic listening:* in many cases, however, the listening becomes particularly intense, concentrated, deeply intimate, regardless of everything else; *Listening by immersion or multi-modal listening: i*t was observed that some children participate with the whole body, bringing into play all every electronic component available; *Symbolic listening:* children dramatise a story or a character that mimic the response of the system, or invent a story while the Continuator's replies serve as soundtrack; *Listening to their productions*, the children are encouraged to listen carefully and compare their productions with the response of the system, to identify repetitions and differences; *Listening "pseudo-distracted*"; Interaction through moments of great effort and time in which the interaction seems loose, but not interrupted; *Virtual Listening:* one of the acts we've seen more interesting is that characterised by staring at an invisible point in space, which characterises the conduct of enjoyment that you have developed with the increasing use of means of reproduction, from the walkman to IPod.

Intertextual listening: finally, the IRMS could be placed in an aesthetics of the fragment and of intertext, being itself by definition a machine that produces intertexts. Listening to it generates in children a kind of intertextual listening during which children are asked to interactively build and reconstruct the fragments of own musical discourse, relaunched by the system, with those of system's answer and the friend's. And it is the variation which attracts the child and motivates him to produce a new answer, to develop a musical idea: to produce, ultimately, musical "meaning".

F. Reflexive interaction and theories of creativity

In general, we can say that the reflexive interaction is a device to stimulate creativity, in our case musical creativity. We have seen that in the infant/adult interaction the introduction of continuous changes in repetitive structures generates a creative (musical) dialogue. Recent studies in neuroscience underline the neural and cognitive mechanisms that allow one to transform and manipulate existing representations. Zatorre (2011) suggests that the dorsal pathway of auditory processing performs equivalent operations on musical inputs. The results allow new hypotheses about how novel musical ideas may emerge from pre-existing musical images (for an overview on musical creativity see Deliège & Wiggins 2006).

As from Pachet (2006) the IRMS's ability to imitate the style of the human playing the keyboard, and its ability to maintain children's attention for long periods of time, has be interpreted through the theory of Flow introduced by psychologist Mihaly Csikszentmihalyi (1996). The indicators of flow experience described by Csikszentmihalyi can be discussed in light of the experiments conducted with children and the IRMS. In our previously study, a systematic observation of flow has been made, and it was 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%) (Addessi et. Al. 2006; see also the paper of the same authors in this Proceedings). We also noticed the presence of the flow indicators as observed by Custodero (2005) in musical experiences. Leman et Al. (2010) and Leman (2010) indicate the theory of *flow* as one of areas of expertise which should be explored to study the human /

machine interaction.

G. Stimulation and therapeutic contexts

It's easy to deduce that the RI has strong therapeutic and rehabilitative potential because it stimulates and activates the interactional processes that involve deeply the person, as well as specific brain areas of resonance. In this sense the IR of IRMS could be an important device in clinical treatments, and become a useful tool for the therapist. For example, Nadel points out that the processes of imitation and imitation recognition are crucial for understanding autism (Nadel 2002). According to Rizzolatti, the autism might have a neurobiology basis in the malfunctioning of mirror neurons. The results of the experiment by Gergely and Watson (1999, cit. in Nadel 2002) and the Nadel's (2002) comments (see above paragraph 12) about the preferred perfect machine temporal contingency by the children with autism are important for our purpose. The fixed temporal contingency, which characterizes the IRMS as perfect machines, along with their imperfect variations in rhythm, melody, timbre, etc., could give rise to a transitional device, preserving both the character of "perfect" machine, as preferred by the children with autism, and the character of imperfect contingency that makes these systems more "human" and close to the social human behaviours. The therapeutic use of IR is still unexplored and novel investigations are being carried out in the framework of the MIROR Project. An exploratory study is being performed with people with autism syndrome (see Anagnostopoulou's paper in this Proceedings) and with a child with Down syndrome (Addessi, Bonfiglioli, Leoni, in preparation).

H. Music analysis of reflexive dialogues

The musical analysis should allow to capture those aspects that characterize the presence of structural variation in repeated patterns, and let to hypothesize how these variations are produced. It represents a perspective of the phenomenon that is not exhaustive, nor are the other, but a necessary perspective to study the RI. As we observed, during the interaction the rules of interaction become musical rules, and this phenomenon suggest interesting perspectives on the connections between RI and onto-genesis of human musicality. The history of the musical language tells us that the processes of imitation and especially repetition / variation were instrumental in the creation of musical language. The musical dimension is within the child's life, one of the fundamental dimensions to communicate, express their emotions. The sound and the way it is organized and perceived by the children reveals much about both cognitive, affective and social life of children. These are some of the raison why the musical analysis is an important step in the study and conceptualization of paradigm of reflexive interaction. The children improvisations revealed rhythmic and melodic patterns, synchronisation on the same pulse, forms of song and accompaniment, individual improvisation styles, brief formal constructions based on imitation, repetition, alternation and contrast. The question is: what kind of musical analysis are we talking about? We make a short list of the kind of music analysis that could be useful in order to "analyse" the RI in musical domain and in children reflexive interaction: *auditive analysis*, *paradigmatic music analysis*, *embodied music analysis*, *computational music analysis*.

V. IMPLICATION: REFLEXIVE INTERACTION IN (MUSIC) PEDAGOGY

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

I. Reflexive requirements

A number of characteristics emerged as being the most interesting to retain and generalize for developing other IRMS in the field of technology-enhanced learning. In short:

- Technical requirements:

Similarity or Mirroring effect; Build virtual images of users; Technically, this image is most of the time imperfect; Scaffolding of complexity; Learn the behaviour of the user; Side-effect; Agnosticity. The basic playing mode: 1. Automatic detection of phrase endings. 2. The duration of the phrase generated by the Continuator should set to be the same as the duration of the last input phrase. 3. Priority is given to the user.

- User requirements:

As far as the mode of interaction: repetition/variation (mirroring, reflexion), turn-taking, regular timing turn, temporal contingency, role-taking, co-regulation, self imitation, imitation recognition.

As far as the user experience: To interact and manipulate a virtual copy of them self, Flow state, dynamic cycle of interaction, invention of rules, joint attention, reflexive listening and thinking in sound, self-regulated and self-initiated activities, self-efficacy, autonomy, intrinsic motivation, music-maker in style

As far as the pedagogical framework: Priority to the children and **l**earner-centred approach, learning by error, the side-effect, adaptation, co-regulation, mirroring, modelling, and scaffolding, starting up 'affect attunement', intrinsic motivation, collaborative playing and joint attention, not to make assessment during the interaction, not to be programmed with fixed musical objectives, to reinforce the children style**,** transparency and reflection, factor of distance: the children are able to interrupt the game when they want.

J. Embodied reflexion in childhood music education

An important extension of IRMS into the MIROR Platform is the pedagogical exploitation of the possibility of communicating with the machine through body "gestures". These issues are addressed by introducing the *expressive gesture analys*is, and it will based on the EyesWeb XMI platform (www.eyesweb.org) (Camurri et al. 2004). The developed techniques are integrated in prototypes of emotional IRMS, addressing live music and dance performance and oriented to pedagogical application in music and dance education. Movement is analysed according to Rudolf Laban's Theory of Effort (Addessi et al. 2012, Volpe et al. 2012). The research in the field of embodied music cognition (Leman 2007, Godoy and Leman 2010), highlights the fundamental role of the body in relation to human musical activities. The concept of "resonance" by Leman has some elements in common with the reflexive interaction and helps to understand better the relationship between the reflexive interaction and the embody cognition, from a action-perception approach to learning. Further studies need to investigate this perspective.

K. What may a teacher learn from the IRMS ?

The results of the observations suggested some reflections on what the human can learn about themselves by observing this system, e.g. the method to teach music improvisation. The "teaching method" of the Continuator is based on its mirror effect, and the strategies of modelling and scaffolding. 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 and it is very difficult to bring improvisation back into western musical culture. So what can a teacher learn from the IRMS? Among other things, to respect turn-taking, 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 curiosity, to develop autonomy; do not make assessments during the interaction; stimulate musical communication, developing learner-centred teaching, adapt his/her teaching practice and method to the cognitive style of the pupils. The teacher may learn to give immediate and concrete feedback to the pupils, to wait and listen to the pupils (as the Continuator "listens" and learns directly from the user), to re-evaluate and emphasize the process of musical creation instead of the musical product and finally to give the priority to the knowledges of the pupils. The IRMS may support teacher and children by creating a framework within which children may in an original way mix new music experiences with the older ones and new skills with the others that have already been acquired. It is interesting to notice how the IRMS may teach the teacher how stimulate and enhance the self-regulation in the daily classroom activities and so to promote an educational style based not only on the teacher/pupils interaction but also based on the peer-to-peer and group interaction (Ferrari et al., in print).

L. The MIROR platform: Applied research in the field of technology-enhanced learning

The MIROR platform is an application of the reflexive interaction paradigm in the field of technology-enhanced learning. The platform is developed in the context of early childhood music education and address improvisation, composition and body performance creation, both in formal situations and informal ones. Several experiments are being carried out in the framework of MIROR project in order to implement the platform and testing it in pedagogical and therapeutic contexts. For more information on the application of the reflexive interaction, see the related literature on the project official website.

VI. CONCLUSION

This paper drafted the theoretical framework of the "reflexive interaction" paradigm and discussed it from a systematic perspective. Starting from the observation of children interacting with an IRMS (interactive reflexive musical system), several theories have been considered to explain human behaviours in action during the interaction with a reflexive system. It was proposed the reflexive interaction could ground a new model of (music) pedagogy in

child/machine interaction. An applied research is currently being performed in the field of technology-enhanced learning in order to implement the first reflexive device for children music creativity. The MIROR platform.

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REFERENCES

Addessi, A.R. (2009). The musical dimension of daily routines with under-four children during diaper change, bedtime and free-play. *Early Child Development and Care*, 179/6, 747-768.

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

Addessi, A.R., Ferrari, L., Carlotti, S., Pachet, F. (2006). Young children musical experience with a flow machine. In *Proceedings of the 9th ICMPC and 6th ESCOM Conference.* (pp. 1658-1665). Bologna: Bononia University Press.

Addessi, A.R., Cardoso, R., Maffioli, M., Regazzi, F., & G. Volpe (2012). The Miror Body Gesture: Designing a reflexive system for children. A pilot study on Laban's Effort features. In *ANPPOM Conference Proceedings*, August 2012, Brazil.

Anzieu, D. (1996). *Les enveloppes psychiques* [The psychic wrapping.]. Paris: Dunod.

Bruner, J. (1983). *Child's Talk: Learning to Use Language.* New York: Norton.

Bullowa, M. (1979). Introduction. Prelinguistic communication: A field for scientific research. In M. Bullowa (Ed.), *Before speech: The Beginning of Human Communication* (pp. 1–62). London: Cambridge University Press.

Camurri, A., Canepa, C. Ghisio, S. and G. Volpe (2009). Automatic classication of expressive hand gestures on tangible acoustic interfaces according to Laban's theory of Effort. In *Gesture in Human-Computer Interaction and Simulation* (pp. 151-162.). Springer Verlag.

Chartrand, T. L. & Bargh, J. A. (1999). The chameleon effect: The perception-behavior link and social interaction. *Journal of Personality and Social Psychology, 76*, 893-910.

Cross, I. (2008). Musicality and the human capacity for culture. *Musicae Scientiae,* Special Issue*,* 147–167.

Csikzsentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience.* New York: Harper & Row.

Custodero, L.A. (2005). Observable indicators of flow experience: a development perspective on musical engagement in young children from infancy to school age. *Musical Educator Research, 7* (2), pp.185-209.

De Kerchove, D. (1991). Brainframes: Technology, Mind and Business. Baarn: Bosch & Keuning.

Deliège, I. (2003). Special issue on Music Similarity. *Musicae Scientiae*, Fall 2003.

Deliège, I., Wiggins, G.A. (Eds). *Musical Creativity.* Hove: Psychology Press.

Deliège, I., Vitouch, O., Ladinig, O. (Eds)(2010). *Musique et Evolution*. Wavre: Mardaga.

Dissanayake, E. (2000). Antecedants of the temporal arts in early mother-infant interaction. In N.L. Wallin, et al. (Eds), *The Origin of Music* (pp. 389-410). Cambridge Ma: MIT.

Ferrari, L., Addessi, A.R. (2012). A new way to play music together: the Continuator in a classroom setting. *International Journal of Music Education*, in print.

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. 123–161). Roma: Carocci.

Godøy, R.G., Leman, M. (Eds)(2010). *Musical Gestures. Sound, Movement, and Meaning*. Routledge.

Gratier, M., Apter-Danon, G. (2008). The musicality of belonging: Repetition and variation in mother-infant interaction. In Trevarthen, C., Malloch, S. (Eds), *Communicative Musicality* (pp. 301-327). Oxford University Press.

Imberty, M (1990). La genèse des schèmes d'organisation temporelle de la pensée musicale chez l'enfant. *Revue des Sciences de l'Education,* 3 - 4, 39-61.

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

Imberty, M. Gratier, M. (Eds.) (2007). *Temps, geste et musicalité*. Paris, L'Harmattan.

Imberty, M. (2009). There is not musicality without intentionality. Return to the origin of human musicality.. In *MERYC2009 Proceedings*. Bologna: Bononia University Press.

Kaye, K., & Wells, A.J. (1980). Mothers' jiggling and the burst-pause pattern in neonatal feeding. *Infant Behavior and Development, 3,* 29–46.

Kohler E, Keysers C., Umilta MA, Fogassi L, Gallese V., Rizzolatti G, 2002, Hearing sounds, understanding actions: action representation in mirror neurons, Science 297(5582), 846-848.

Laban, R. (1980). *The Mastery of Movement*, London, Macdonalds & Evens Limited, 4th Edition.

Lakin, J. L., & Chartrand, T. L. (2003). Using nonconscious behavioral mimicry to create affiliation and rapport. *Psychological Science, 14*, 334-339.

Leman, M. (2007). *Embodied Music Cognition and Mediation Technology*, Cambridge, MA: MIT Press.

Leman, M. (2008). *Systematic musicology at the crossroads of modern music research*. In A. Schneider (Ed.). *Systematic and Comparative Musicology: Concepts, Methods, Findingspp* (pp. 89-115). *Hamburger Jahrbuch fur Musikwissenschaft*, 24, Frankfurt am Main: Peter Lang.

Leman, M., Lesaffre, M., Nijs, L., Deweppe, A. (2010). User-oriented studies in embodied music cognition research, *Musicae Scientiae*, Special Issue, 203-224.

Malloch, S. (2000). Mothers and infants and communicative musicality. *Musicae Scientiae,* Special Issue, 29-58.

Mazzoli. F.(2003). I suoni abitati. In F. Mazzoli, A. Sedioli & B. Zoccatelli, *I giochi musicali dei piccoli* (pp. 7–17). Bergamo: Edizioni Junior.

Meltzoff, A., Prinz, W. (2002). *The Imitative Mind.* Cambridge: Cambridge University Press.

Meeùs N. (1993). Le rapports associatifs comme déterminants du style. *Analyse Musicale*, 32, 9-13.

Mitchell R W. (2002). Imitation as a perceptual process. In K. Dautehahn & C L Nehaniv (Eds), *Imitation in Animals and Artifacts* Cambridge MA: MIT Press

Mithen, S. (2005). *The Singing Neanderthals: The Origin of Music, Language, Mind and Body*. Londres: Weidenfield & Nicolson.

Murray, L., & Trevarthen, C. (1985). Emotional regulation of interaction between two-month olds and their mothers. In T.M. Field & N.A. Fox (Eds), *Social Perception in Infants* (pp. 177–197). Norwood, NJ: Ablex.

Nadel, J. (2002). Imitation and imitation recognition: Functional use in preverbal infants and nonverbal children with autism. In Meltzoff, A., Prinz, W. (Eds)(pp. 42-62).

Nadel, J., Butterworh, G. (Eds) (1999). *Imitation in Infancy*.

Cambridge University Press, Cambridge.

Nattiez J.-J. (1987). *Musicologie générale et sémiologie.* Paris: Bourgois.

Nehaniv, C., Dautenhahn, K. (Eds)(2007). *Imitation and Social Learning in Robot, Humans and Animals*. Cambridge University Press.

Pachet, F. (2003). Music interaction with style. *Journal of Music Research*, 32(3), 333-341.

Pachet, F. (2006). Creativity studies and musical interaction. In I. Deliège & G.A. Wiggins (Eds) (pp. 347-358).

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

Pachet, F., Roy, P., Barbieri, G.(2011). Finite-Length Markov Processes with Constraints, *Proc. of IJCAI 2011*, July, Barcelona.

Papousek, M. (1995). Le comportament parental intuitif, source cachée de la stimulation musicale dans la petite enfance. In I. Deliège & J. Sloboda (Eds.), *Naissance et dévelopement du sens musical* (pp. 101–130). Paris: Presses Universitaires de France.

Papousek, M. (2007). Communication in early infancy: An arena of intersubjective learning. *Infant Behavior and Development, 30,* 258–266.

Rizzolatti, G., Fadiga,L., Gallese, V., Fogassi, L. (1998), Premotor cortex and the recognition of moto actions. *Cogntion Brain Research*, 3/2, 131-141.

Rizzolatti, G., Fadiga, L., Fogassi, L., Gallese, V. (2002). *From mirror neurons to imitation: Facts and speculations*. In Meltzoff, A., Prinz, W. (Eds), pp. 247-266.

Rochat, P. (2002). Ego function of early imitation. In Meltzoff, A., Prinz, W. (Eds), pp. 85-97.

Ruwet, N. (1966). Méthodes d'analyse en musicologie. *Revue belge de Musicologie*, 20, 65-90.

Stern, D. (2004). *The Present Moment in Psychotherapy and in Everyday life*. New York: Norton.

Toiviainen, P. (Ed.) (2007). *Similarity perception in listening to music*. *Musicae Scientiae*, Discussion Forum A/B.

Trevarthen, C. (2000). Musicality and the intrinsic motive pulse: evidence from human psychobiology and infant communication. *Musicae Scientiae,* Special Issue, 155-215.

Turkle, S. (1984). *The Second Self: Computer and the Human Spirit*. New York: Simon-Schuster.

Volpe, G., Varni, G., Mazzarino, B., Addessi, A.R. (2012). BeSound: Embodied reflexion in childhood. *IDC 2012 Proceedings*, Germany.

Webster, P.R. (2007). Computer-based technology and music teaching and learning: 2000-2005. In L. Bresler (Eds), *International Handbook of Research in Arts Education* (pp. 1311-1328). The Netherlands: Springer.

Young, S. (2003). The interpersonal dimension: A potential source of musical creativity for young children? *Musicae Scientiae* Special Issue, 175–179.

Zatorre, R. J. (2011). Beyond auditory cortex: working with musical thoughts, *The Neuroscience and Music-IV Learning and Memory Conference*, Edinburgh 2011.