Enacting teaching and learning in the interaction process: "Keys" for developing skills in piano lessons through four-hand improvisations

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Abstract: Embodied mind theories underline the role of the body in the act of knowing. According to the enactive approach, we learn to perceive and to know through our bodily interactions with the world (Varela, Thompson & Rosch, 1991). However, such an approach remains incomplete as long as sociality is not taken into account (Froese & Di Paolo, 2009). Recently, an inter-enactive approach has accordingly been proposed. Social interactions are seen as processes of coordinated sense-making that emerge from the dynamics of the *inter*-action process itself (De Jaegher & Di Paolo, 2007). As learning mainly takes place in intersubjective contexts (e.g. as an effect of teaching), this approach is relevant to the issue of pedagogy. Teaching settings are a special case though: cognitive interactions are reciprocal but asymmetrically guided by the teacher. In this paper, the question of the relations between body and education is thus addressed from the point of view of the inter-enactive approach. To this end, we first sketch out the phenomenological and theoretical contours of embodied intersubjectivity and intersubjective embodiment. Then, we present an interactive pedagogical method for musical learning (free spontaneous four-hand improvisations in the context of the Kaddouch pedagogy) and discuss it using illustrative case studies. The teacher's role appears to operate directly within the dynamics of the interaction process, a source of knowing and skill enaction for the learner.

Keywords: enaction, interaction, coordination, teaching, learning

Introduction

Etymologically, pedagogy means "guiding a child" and broadly refers to the methods used in education. It therefore implies a "complementary pair" (Kelso & Engström, 2006): teaching~learning[1]. Indeed, teaching would not be complete without subsequent learning, and one would not speak of pedagogy where learning happens without teaching. While "teacher" and "learner" are socially prescribed roles, for actual teaching and learning to occur, these potential roles have to be enacted, that is, actively actualized through complementary actions. Education is thus an inherently intersubjective process. We will accordingly consider a pedagogical situation involving a teacher and a learner as an archetypal and relevant starting point from which to discuss the fundamental processes involved in education.

Teaching generally aims at changing learners' cognition in the broad sense of the term (referring to both "know-how" and "know-that" capacities). For this purpose, teachers have to figure out what learners already know, and what they do not (what they still ignore or cannot do), both before and after learning takes place (in order to evaluate its effectiveness; Kostrubiec, Zanone, Fuchs & Kelso, 2012). Education therefore implies communicative processes about learners' cognition (i.e. their interrogation by the teacher and their expression by learners themselves) and mutual understanding. Thus, teaching involves some knowledge of how to communicate in order to guide learners towards learning. Education consequently involves cognition about communication on top of communication about cognition.

In this paper, we address the question of the relations between cognition and communication in teaching~learning processes. To coherently provide for both a theoretical framework and educational methodologies, this endeavor is co-conducted by a researcher (from the cognitive sciences) and a pedagogue (of musical education). In the first part, we outline the theory, particularly by referring to recent propositions formulated in the enactive approach to the study of the embodied mind (Varela, Thompson & Rosch, 1991) and by dynamic approaches to the study of behavior (Kelso, 1995), both of which are contrasted with the more classical but criticized positions with which we open the article, and in keeping with observations from developmental and social psychology, which we present afterwards. Taking into account the embodiment of cognition and communication leads us to

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[1] The tilde (~) sign, or squiggle character, is a reference to Kelso and Engström (2006). It designates the "complementary aspects of complementary pairs" of concepts (p. 7). In other words, it denotes the incompleteness of each concept of the pair when it is considered in isolation of its complementary aspect and thereby points out the dynamical nature of their relations.

refine our view of these terms and their relations. Studying interactive processes seems to be especially important if we are to understand how the inherent intersubjectivity of pedagogical situations contributes to learning. In the second part, we illustrate this view using Kaddouch's pedagogy for learning music (Kaddouch & Miravète, 2012), and finally we discuss some case-studies. By focusing on teaching~learning coupled processes, we hope that a generalizable framework will emerge and inspire both practitioners and researchers in their endeavor to understand and improve education.

Theoretical contours

Classical Psychology of Cognition and Communication

Traditionally cognition refers to a general explanatory scheme: perception –> cognition –> action (Hurley, 1998). Cognition primarily consists in the formation of *internal* mental representations about the *external* world, in order to act adaptively in that world (Varela, 1988). These "mental states" serve as an interface between the separate aspects of perception (the input of information flowing from the world that has to be cognized) and action (the adaptive behavior driven according to such cognitive representations). In this perspective, the most important processes occur "in the head" of the individual cognizer, whereas explicit behaviors are solely peripheral applications of mental representations.

This view is found in the classical model of communication by Shannon and Weaver (1948): information flows from one emitter to a receiver via a medium. Individual actions are thought separately, successively: each partner takes turn in perceiving the message emitted by the other, understands it, and "inter"-acts accordingly. Understanding the other thus involves identifying the mental states that caused the emitted message or behavior. In other words, as pointed out by De Jaegher (2006), understanding each other and participating in social interactions would be a matter of individual mental processes: the social situation itself should not bring much to it, and the role of the body seems peripheral, non-constitutive of the processes at work (at best, the body conveys tangible information that manifests its hidden mental causes).

The classical approach to human understanding has received a lot of criticism (Varela, 1988), as has its inherent perspective on mutual understanding (De Jaegher, 2006). We briefly identify three inter-related phenomenological axis of criticism which address the issues of corporality, temporality and sociality in intersubjective understanding.

Criticism of Classical Approaches

In the classical perspective, understanding an other is mediated by mental representations formed in the individual mind, while the body solely conveys meaningless visual information that serves as raw input for higher-level cognition (Gallagher, 2008). However, our habitual experience of understanding an other is *im*-mediate: we *directly* perceive the expressivity of his body, with no separation of the expressed and the expression (Merleau-Ponty 1945), that is, of mind and behavior. The meaning of behaviors seems transparent, rather than opaque and hidden in an abstract mind (De Jaegher, 2006). We can then speak of "body-reading" (Gallagher, 2001) rather than "mind-reading" (Baron-Cohen, 1994).

Giving a central role to the mental mind and a peripheral one to the body prompts us to see the individual cognizer as a static and passive observer. However, we are actively engaged in the dynamics of the situations we live through. These situations have a temporality that matters (it is not enough to do the right thing, it has to be done at the right time), especially in social interactions where timing constraints are very tight and make sense (Nijholt et. al., 2008). Social interactions then are dynamical continuous flows rather than successions of mental *states* (De Jaegher, 2006).

More over, the active role of the body modifies the very situation that would have had to be observed in the first place: we do not just act *in* the world, we interact *with* the world, in a timely fashion. In other words, rather than being a detached observer of an external world, the cognizer is pragmatically involved in his own world. During encounters with others, we thus participate in the social interaction itself. As pointed out by De Jaegher (2006), we are connected both to the social situation (in which we feel immersed) and to the other (with whom we feel a sense of "being together"). It is difficult to explain such experiences from the detached vantage point from which connexion with the external world is mediated by internal representations.

Overall, a simple succession of individual mental states cannot account for our lived experience of social situations in which mutual understanding is pragmatic and concrete rather than abstract. The background of mutual understanding seems to involve more fundamental capacities. What shape does this background take when it is observed in early infancy, when behavior cannot rely on highly-elaborated abstract cognition?

Early Intersubjectivity

Parents educate their children in order to guide them in a shared world of human understanding. In fact, newborns already seem intrinsically motivated to maintain *sym*-pathetic relations with adults, and capacities

to participate in interactions develop very early (Trevarthen, 2011). Such "primary intersubjectivity" capacities imply both the display of subjectivity (by expressing the intentionally directed nature of one's own behavior through the coordination of gestures) and the adaptation of this kind of subjectivity to another (Trevarthen, 1979). This allows the experiences expressive actions carry to be shared. These capacities are not mere imitative responses or reactions: babies' communicative acts invite adults to share the coordination of their behavior with them (Trevarthen, 2011). Indeed, Murray and Trevarthen (1985) showed that children actively participate in communicative interactions. They compared mutual interactions (mediated by TV monitors) between two-month-old infants and their mothers and the interactions of these children with a (non-responsive) recording of the same interactional sequences. Though the babies observed the exact same behavior of the mother in both situations, they reacted very differently to the recording, showing anger and frustration and losing interest in the interaction process. What babies seem to be aware of is the lack of contingency between what they do and what their mother does. Therefore, interactivity itself plays a role in their experience. The lack of opportunity to contribute to the regulation of the unfolding interaction frustrates them. On the other hand, through their active contribution to the communicative processes, their coordinated activity becomes part of the interpersonal contingencies, which they can therefore actively experience in an un-mediated but direct and pragmatic manner.

Synchrony between mother and infant is in fact important in the latter's development (Feldman, 2007) and this kind of temporal coordination is very fine-grained. For instance, movements of new-borns synchronize with the speech of adults (Condon & Sander, 1974). Early synchronous coordination generally has a rhythmical nature (Trevarthen, 1999; Gratier, 2008): interactions are structured around implicit and shared "pulses" and exhibit coherent temporal organization on several time-scales, forming phrases and narrative episodes (Malloch, 1999). The stability of the pulsatile, rhythmical recurrences provides an attentional framework for the anticipation and coordination of activities (Large & Jones, 1999; Gratier & Apter-Danon, 2009). Early interactions are not metronomically regular though: timing deviations are observed (Gratier, 2003). These subtle variations are functional: they are expressive and stimulating, as they "vitalize" the contour of lived experiences whose meaning can then be shared with subtlety (Gratier & Apter-Danon, 2009; Stern, 1985). This flexibility produces surprises in the anticipated unfolding of the interaction, thus sustaining attention by actively engaging both mother and child in the communicative processes. In this regard, moderate contingencies (rather than either rigidly regular or random ones) lead

to positive outcomes in cognitive and affective development (Jaffe, Bebee, Feldstein et al., 2001; Hane, Feldstein & Dernetz, 2003).

Overall, early processes of meaning sharing involve tight behavioral co-ordination. Furthermore, such fundamental capacities are at work in adult interactions as well, as observed in many experiments and conversation analysis (e.g., Condon & Ongston, 1971; Bernieri & Rosenthal, 1991; for reviews, see Richardson, Dale & Shockley, 2008; Shockley, Richardson & Dale, 2009; or Dale, Fusaroli, Duran & Richardson, 2014). In short, mutual understanding during social interactions does not seem to primarily involve successive individual mental states, but implies simultaneous and collective embodied dynamics. To further understand this kind of phenomenon, we turn to the enactive approach, as it constitutes a paradigmatic shift from classical representationalism (Varela, 1988), illuminates the embodied nature of human cognition (Varela et al., 1991) and accounts for cognitive behaviors in their intersubjective contexts of emergence (De Jaegher & Di Paolo, 2007).

The Enactive Approach

Instead of positing an objective informational world and wondering how it could be represented within the mind, the enactive approach addresses cognition from the point of view of the reality of the organism itself (Varela et al. 1991). Here, the mind is embodied in the sense that cognition is both a *living* (biological) and a *lived* (experiential) phenomenon.

Living is defined by its own organization: a closed network of inter-related processes whose interdependence gives rise to a coherent unit (Varela, 1979). In turn, a system like this sustains itself by constraining the very operations from which it emerges. By doing so, the living unit produces its own *id*-entity (Varela, 1997) and therefore defines its own norms, that is, the conditions under which its organization is maintained. The organization of the living is thus auto-nomous (self-laws; Varela, 1979). As it is self-producing, the living system distinguishes itself from the environment: it defines what it is not and thereby constitutes its own world from its own perspective. This perspective has intrinsic values: the kind of relations the living system can have with its environment while being autonomous. It then exists and lives in the *relational* domain of its coupling with the world, the latter becoming valued by and meaningful to the living system (Varela, 1997). When such an entity modulates its coupling autonomously (by modifying its environment or by regulating its internal organization and activity so as to change the value of this coupling), we can speak of the interactive autonomy of an adaptive agent (Barandiaran, Di Paolo & Rohde, 2009). Cognition is

consequently defined as a sense-making activity that consists in enacting a significant world through autonomous interactions with the environment (Di Paolo, 2010). Behavior thus expresses the coupled relation of the agent with its world: it expresses the meaning this agent "imbues" its own world with (McGann, 2010). Therefore, behavior and meaning are relational phenomena: they are situated in the coupling of an agent with its world (but not solely in the former, nor in the latter).

Phenomenologically, the lived world of an organism is imprinted by its own embodied structure (Maturana & Varela, 1987), that is, both by what it can sense and what it can do. Indeed, as motility shapes the part of the environment that can be sensed (e.g., turning your head displays renewed visual sensations; see Merleau-Ponty, 1945), sensori-motor coupling pragmatically connects us *with* the world it gives rise to (i.e. instead of *to* the world, by mediating mental or neural representations for instance). In other words, the lived world emerges in the relational perspective of the agent–world coupling. Skillful mastery of this meaningful coupling thus shapes our lived experiences (Thompson, 2005). In this context, the body can be experienced either as a living or as a lived phenomenon (following the distinction made by Husserl, 1952). The living body is the image or view one can have of it through observation, while the lived body is the *point* of this view, the unified meeting of sensation and action affordances, the null-point from which we can pragmatically relate to the world (Lenay, 2010; Thompson, 2007). We do not see the place or point from which we see: the lived body is transparent in experiences (otherwise it would obstrue those very experiences; Lenay, 2010). It is not absent though, as it anchors and contributes invisibly but constructively to such experiences, like the look that is involved in what is seen: the lived body is thus *pre*-reflective (it is not a thematized object of consciousness; Thompson, 2007). Without this bodily self-consciousness, we could not have personal experiences at all (i.e. that implicit feeling of being present in a world we experience ourselves). As a consequence, whatever is transparently part of our action~perception loops participates in our relational and pragmatic connexion with the world: it is therefore *in*-corporated in the lived body (like the glasses through which we see but that we forget are on our nose, or the cane of a blind man who "senses" the ground through it; see Merleau-Ponty, 1945, or Heidegger, 1927). What are the consequences of such an embodiment in intersubjective contexts, and what role does it play in mutual understanding?

The Enactive Approach to the Study of Intersubjectivity

During social encounters, the lived body partly becomes a living body for an other (Lenay, 2010). Indeed, Lenay points that although part of our

expressivity is invisible to ourselves (e.g., the look and facial expressions that we do not see), they are visible to the other. Our expressive activity can then affect and change the other who perceives us. Through the reciprocity of such action~perception effects, we become linked to the activity of each other, like when we both pull a rope in different directions. The other thus becomes part of our pragmatic experience and vice-versa: by interacting, we mutually incorporate each other's perspective in our lived experiences (Fuchs & De Jaegher, 2009, following Merleau-Ponty, 1945). If sense-making emerges from the embodied activity of the subject, and if the sensori-motor dynamics of encountering subjects become coupled, then we participate in the sense-making of each other (De Jaegher, 2006), a process that De Jaegher calls "participatory sense-making". In other words, mutual understanding can emerge from interactive and reciprocal modulations of individual sense-making (De Jaegher & Di Paolo, 2007). Interaction is thus the locus of emergence and transformation of meaning (De Jaegher, 2006): it is where sense can be shared and can become common.

The meeting of embodied perspectives opens up a new phenomenological and cognitive domain that is specific to intersubjective encounters (i.e. it is irreducible to the individual participants and their internal processes; De Jagher & Di Paolo, 2007). This domain is constituted by the dynamics of the *inter*-active process itself. Indeed, on the one hand, the other escapes us constantly as we change him (Lenay, Stewart, Rohde & Amar, 2011), while on the other hand, as the other we changed changes us in return, we come to change ourselves during interactions and thereby constantly escape ourselves too (Lenay, 2010). The interaction process as a whole then escapes us. It can thus become dynamically autonomous and obtain a "life of its own" (De Jaegher & Di Paolo, 2007). By acquiring a certain stability (Froese & Di Paolo, 2008; Laroche, 2013), the interaction process takes the shape of an attractor which coordinates individual activities (Auvray, Lenay & Stewart, 2009; Laroche, 2013) and can therefore modulate individual sense-making. In this way, relational dynamics that exist between subjects attract their respective internal dynamics towards behavioral territories that are not available to them when they are isolated (Froese & Fuchs, 2012). Interaction processes can thus transform and enhance the behavioral repertoire of the individual subjects (and thus their means of meaning; De Jaegher, 2006). Furthermore, as we are collectively affected and shaped by interactional processes, not only do we incorporate each other's perspective, but we also transparently incorporate the dynamics of the interaction process itself (De Jaegher, 2009). In other words, we embody such collective dynamics (Rhode, Leany, Stewart, et al., 2012): they orient our explicit bodily activity and modulate our lived experience. By efficiently transforming

our point of view, interactivity thus gives access to new shared meanings that emerge intersubjectively (De Jaegher, 2006). In short, the interaction process can *trans*-form individual sense-making, giving rise to a domain of *com*-prehension that is not available to the isolated subject (De Jaegher, Di Paolo & Gallagher, 2010). Overall, not only does the coordination of behavior maintain social interactions (Kendon, 1970), but interactions also entail coordination (De Jaegher, 2006; Laroche, 2013).

Obviously, the mere presence of interaction processes does not guarantee our perfect coordination. If so, we would become locked into each other (De Jaegher, 2006) and we would no longer be able to have personal perspectives. That would prevent new meanings from emerging, and encounters would become worthless at some point. However, because our embodiment constitutes a point of view, our encounters tend to be incomplete: we escape each other constantly (Lenay, 2010). The resulting autonomy of the interaction process thus does not absorb the autonomy of the participating individuals (Di Paolo & De Jaegher, 2007). As a consequence, interactive coordination is a perfectly imperfect process, and can thus suffer coordination breakdowns (De Jaegher, 2006). As De Jaegher points, such breakdowns are important, as they maintain the personal, involved and participative engagement of the autonomous subjects, so that the process of interaction can be repaired. Here again, the interaction process is the locus of meaning emergence, transformation and sharing. Thus, both (individual and collective) autonomous levels regulate each other interactively. The quality of social experiences lived from a first-person perspective therefore depends on the upstream emergence of the very intersubjective character of such experiences. In other words, intersubjective dynamics precede their individual appropriation or recognition (see Lenay & Stewart, 2012). To make sense of, to, and with the other, we thus have to enact and regulate skillfully the relational dynamics that emerge from the in-between of our interactions (McGann & De Jaegher, 2009). In asymmetrical situations such as teacher~learner relations, the role of one person is to coordinate the other, while the learner should supposedly coordinate *to* the teacher (borrowing the distinction between coordination "to" and "with" from De Jaegher, 2006). Mutual understanding is then still at play in education, as what has to be modulated in order to guide and transform the learner's sense-making activities is the relational dynamics, and interacting is the most fundamental way of doing this.

How can we properly study the way meaningful behaviors are coordinated in the course of interactions? As activities are rhythmically structured (Morowitz, 1979; Kelso, 1981), the effect of mutual coupling should lead to emergent interactional rhythm (De Jaegher, 2006), thus entailing the kind

of fine-grained temporal coordination that is at the core of social interactions (see "early intersubjectivity"). In this regard, dynamic systems theories provide formal tools and concepts that naturally fit phenomenological descriptions (Varela, 1996; Froese & Fuchs, 2012; Froese & Gallagher, 2012).

Coordination Dynamics and Learning

Coordinative phenomena are actually ubiquitous in nature (from heart cells and insects, to atoms and pendulum; see Strogatz, 2003) and follow similar dynamic laws on multiple scales of observation (e.g., intrapersonal coordination, coordination with environmental features or between-persons coordination; see Kelso, 2009). Such phenomena have thus become a topic of study on their own, referred to as "coordination dynamics", the science of patterns formation, persistence and dismantlement (Kelso & Engström, 2006). Here, temporality (dynamic laws of change) is taken into account, as well as the articulations between the individual level of component processes and the collective level at which they *co*-ordinate (Kelso, Dumas & Tognoli, 2012). The following two paragraphs quickly summarize the work of Kelso and his colleagues (e.g., Kelso, 2005, 2009; Kelso & Engström, 2006).

Broadly, mutual adjustments between the operations of components (e.g., neurons, limbs or persons) result from their reciprocal interactions, giving rise to synergistic behaviors (Bernstein, 1967). Thus, the variability of component processes provides them with a tendency to *co*-operate, which accounts for coherent pattern formation. In turn, such synergies constrain operations at the component level, accounting for the persistence of coordinated patterns of behavior. In this context, stability is observed at the relational level of organization (i.e. how component processes relate to each other) and can be captured by collective variables that measure their coherence. Stable relations among components thereby constitute attractors for the system which then "prefer" to adopt such patterns, accounting for behavioral regular recurrences. However, components retain a tendency for autonomy by expressing their own dynamics. This provokes fluctuations in the system which are "functional" in the sense that they "test" the stability of patterns by destabilizing them. This provides flexibility and opportunities for change when patterns do not fit the situation so that a new one can emerge. In this regard, both exogenous factors (task instructions, environmental conditions) and endogenous factors (motivation, intention) can act as control parameters, that is, quantities whose changes can lead to pattern reorganization, accounting for both pattern dismantlement and behavioral adaptive switching. Such changes at the level of the coordinated system as a whole are often abrupt transitions, taking the form of a leap in the eye of the beholder.

Patterns of behavior thus emerge from the background of co-existing tendencies (autonomy~cooperation tendencies and the potentially stable relations between components in the current situation). The shape of this background is therefore a dynamical landscape made of basins of attraction and repelling patterns that orientate behavior as mountains guide waterways. Such "intrinsic dynamics" form a kind of pre-existing repertoire of spontaneous tendencies which reflects our individual history: this is what we bring with us into interactions, and such dynamics constrain and shape the patterns that can be learnt or stabilized (Kostrubiec, Zanone, Fuchs & Kelso, 2012). Learning thus takes place in the context of such a background and consists in the modification of such intrinsic dynamics. Learning then depends on the relation between new information or to-be-learnt patterns and pre-existing intrinsic dynamics. Therefore, teaching~learning processes imply the guidance of such relations. One of the teacher's roles consists in setting the conditions that are involved in the organization and shaping of the learner's dynamics, by encouraging reorganization through task constraints and other control parameters. As we have seen, interacting is indeed a powerful way to modulate such behavioral organization, as demonstrated in numerous social interaction experiments (see Oullier & Kelso, 2009, for a review).

The Kaddouch pedagogy: Teaching music through improvisation

To illustrate how the above presented concepts can be applied in particular educational situations, we will now turn to the Kaddouch musical pedagogy (Kaddouch & Miravète, 2012), as its practice and the observations it leads to tend to echo our theoretical background. Here, we focus on the use of improvisation for learning the piano. We describe the method and the concepts that have emerged from the practice, and then interpret them in the light of our theoretical sketches. We then present and discuss case-studies that are both idiosyncratic and representative of the observations that can be made during such lessons. Our analysis relies on recordings of the improvisation sessions and their analysis by the teacher, without prejudicing and modifying the habitual reality of these sessions (see Kaddouch & Laroche, 2014, for a more musicologically oriented analysis). Accordingly, these analyses are qualitative and clinical: they represent a first step in the merging of enactive and dynamicist perspectives on the one hand, and the Kaddouch pedagogy on the other. These observations will lead to further empirical research to be addressed in the future.

Method

Improvisation is an important tool in the Kaddouch pedagogy. Here, we will focus on free spontaneous (i.e. without explicit instruction) four-hand piano improvisations: a child learner sits on the right (playing medium and high notes) while the teacher sits on the left (playing the medium and low-end notes on the piano). In this context, teacher and learner experience the same situation: both of them do not know what the other will do or play. This situation is thus problematic and unprecedented for both of them (Kaddouch & Miravète, 2012). Indeed, as the outcomes of the unfolding improvisation cannot be known in advance, the problem of creating and playing communicatively does not allow for the solution to be identified before the actual situation occurs. Although such problems are shared, they are also asymmetrical. Indeed, the pedagogical, musical and instrumental expertise of the teacher provides him with the means and tools to help the learner to solve these unprecedented problems with him. The practice of such pedagogical situations and observations has given rise to several concepts: spontaneous achievement zones, phase of synchrony, phase of diachrony, core tastes and lightning learning. We define them by underlining their relations to the above theoretical propositions. We then illustrate them "in acts" using case-studies.

Concepts

During improvisation, learners exhibit clear individual preferences for certain patterns that they tend to adopt on a regular basis, and they do so without constraints or explicit instructions. Though these patterns can take various shapes (e.g. by using different notes, intervals or kinds of gestures), they seem to derive from common frameworks that are embodied with ease and which we call "spontaneous achievement zones". Notions like motor command or abstract programs defined in advance of the situations to which the behavior should fit barely capture this kind of phenomenon. Instead, the phenomenology of preferred behavioral patterns seems to be better captured by the ideas of attracting tendencies and intrinsic dynamics that shape the background from which behaviors can emerge. In dynamicist language, spontaneously achieved patterns should be stable solutions for these intrinsic dynamics. One of the teacher's roles then is to probe and identify these zones by interacting through improvisation, and to set up the conditions which favor the emergence and unfolding of such patterns.

To provide such a favorable context, a central technique consists in mimetic or complementary responses. Such imitations or complementary actions lead to "phases of synchrony", during which learner and teacher are

"together" in the interaction: they share the "same time" and resonate in each other's movements. The functional role of the phases of synchrony is to validate the patterns proposed by the partner, entailing the sharing of experience and meaning. Synchrony also offers an anchor for the learner to further stabilize his movements, so he can become freer to explore new possibilities of behavioral expression.

However, if they stay locked in synchrony, the partners would stop bringing anything new and relevant into the situation: meaning would no longer be negotiated and shared. In other words, the partners would stop communicating and cease to be personally engaged in their encounter. In order for new meanings to emerge, the situation has to be kept problematical and unprecedented, and this is the role of the teacher. For that purpose, he can use "blocking actions", that is, patterns that do not fit those the learner currently adopts. It entails a "phase of diachrony", during which partners are no longer together (i.e. they do not embody the same unfolding temporal organization). Coordination breakdowns such as these mean that a new meaningful solution has to be worked out in the course of interaction. Therefore, phases of diachrony consecutive to blocking actions are an opportunity to make new propositions that could repair the interactional failure. This makes the flexible engagement of the learner a necessary condition for the communication to go on and to keep making sense. He now has to reorganize his own gestures so they fit the intersubjective situation again. It is thus an opportunity for change so new ways of uncovering problematical and unprecedented situations can be learnt, and this happens in the dynamics of interaction.

As a result, the blocking technique provides a means of achieving behavioral patterns that are out of the "comfort zone" of the learner's spontaneous achievements. The learner might therefore do things he could not do by himself. By extension, he might be able to accomplish desired behaviors. This leads us to the notion of "core tastes", which broadly refers to the desires of a person about the way he would like his lived experience to be. Distinguishing between core tastes and behaviors that belong to the spontaneous achievement zone is made possible by interacting and is a pedagogical end in itself: the role of the teacher is to help the learner not to stereotype his spontaneous achievement zones, as they could mask the expression of core tastes.

By enabling the emergence of patterns of expression that are different from those that the learners already knows and spontaneously adopts, such a pedagogical tool can help learning and the acquisition of new "means of meaning". In this context, instead of being long and painstaking, learning new techniques often has a "lightning" quality: it happens suddenly,

similarly to phase transitions observed in dynamic systems where behavior switches from one pattern to another. Let us now present and discuss three case-studies that illustrate these concepts.

Case studies

Albane

   Albane (names have been changed) is a 7 year-old-girl who has been learning piano in this pedagogical setting for two years. She enjoys improvising, and requests it each lesson.
   In this session, Albane begins with a gesture she performs easily at a tempo she's comfortable with. The rhythmical pattern belongs in her spontaneous achievement zones: its stability seems to reflect an attraction to intrinsic dynamics, a necessary condition for her to begin improvisation. The teacher validates her choice by imitating her gestures and speed, as if they made sense to him too. They thus enter a phase of synchrony. The coordination of their actions provides an anchor for Albane's movements to be further stabilized. Indeed, she can now rely both on the consistency of the teacher's gestures and on the stabilizing effects of the interaction process itself in order to off-load her coordinative efforts (Laroche, 2013).
   The teacher then proposes a different harmonic and rhythmical pattern, a blocking action that entails a phase of diachrony. As a consequence, Albane makes rhythmical and melodic mistakes: because it has been destabilized, her gestural pattern fluctuates. Note that this is a consequence of the instability of the interaction process itself: the teacher's and learner's musical patterns no longer fit together. The learner's playing is thus no longer relevant to the intersubjective context. The coordinative attraction of the interaction process makes it difficult for her to maintain her initial pattern with ease (despite it belonging to her spontaneous achievement zone!). Her mistakes are indeed a sign of communication and underline both the appealing effect of the interaction process and her temptation to regulate it, by seeking to reorganize her gestures so as to fit the newly established musical context. Albane ends up with a brand new pattern that is coherent in the shared context. A new phase of synchrony has emerged and she explores it through numerous variations. At this phase transition (from diachrony to synchrony), the attractor that exerted influences on her behavior seems to migrate from an intrinsic dynamic landscape towards collective dynamics. The new phase of synchrony is thus richer than the previous one: it has been achieved through mutual propositions and regulated adjustments, plus it allows for both pattern stability and flexible variations. The meaning

of this phase is intersubjectively situated, as isolated partners would not and could not have reached and shaped it in this way. This co-enactment seems meaningful in itself for the social embodied experience of the learner, as Albane starts dancing on her seat, which reflects a deep resonance between her and the *inter*-actively created music.

After this, the teacher starts a transition towards the first musical theme. Albane switches immediately to her initial pattern, reflecting its stability and the appeal of her own intrinsic dynamics which her behavior seems to be "pulled towards". However, this phenomenon is transitory as she quickly adopts a new kind of pattern: a new rhythm, a new speed, and new gestures. This pattern does not emerge from scratch, though: it is an extension of the proposition that the teacher had previously made. Through cooperative interactions, her embodied perspective has been adaptively transformed and she can now escape the routine of her spontaneous achievement zones by reorganizing her expressive gestures.

Later on, an even subtler kind of synchrony phase can be observed. Through a succession of mutually agreed validating and blocking actions, Albane and the teacher enter a phase of synchrony that is situated at a higher-order temporal level: they play with the structure of the interaction process itself. This shows that Albane is sensitive to and aware of the relational dynamics of the interactive situations. She is able to appropriate the dynamics she helps regulate explicitly, up to the point that she can literally thematize them with her teacher. For his part, through his mastery of the interactive dynamics, the teacher can guide them in order to extend the space of possible behaviors for the learner. By exploring further behavioral regions, the learner can escape the attractors that trap his behavior and can thus express his core tastes. In the case of Albane, her expressive dance on her seat signals to us that she takes pleasure in creating new meaningful patterns in resonance with the teacher. More generally, she seems to deeply enjoy playing with the interaction dynamical principles themselves. The learner can thus realize herself through the interaction process, with guidance from the teacher but also through her own contribution. It seems that it is in the inter-actively shared contexts that significant meanings can be brought forth and can realize the core tastes of the learner. It also seems that such core tastes make sense when they are experienced with another person.

In this context, learning can have a lightning quality, in the sense that the invention and appropriation of new techniques occur at speed during the course of improvisation. To grasp this lightning dimension, one should consider how difficult it would be to teach these techniques verbally, explaining how, why and especially when these patterns would have to be

used, as the improvisation situations are unprecedented (i.e. one cannot know in advance how they will unfold). The acquisition of new patterns can take such an abrupt shape because it emerges from an interactive situation that makes the behavioral reorganization necessary. The intersubjective dimension of the pedagogical situation can therefore be constitutive of the acquisition of a skill or technical knowledge. The learner does not need to "possess" fully the ability to command such patterns in advance of the particular situation for these patterns to be coordinated. Instead, the learner can rely on the constraints of the interaction process itself to modulate her own behavioral organization in relation to this interactive context. The learner could be pulled towards relational coherence and stability, and that makes her wish to acquire new skills and new means of communicating and sustaining the interaction. In a nutshell, skill acquisition is embodied in the collective dynamics of the interaction that attract behaviors. Of course, this is not enough to guarantee the long-term stability of the new behavioral pattern (Kostrubiec et al., 2012). However, by means of recurrent interactions, patterns could be stabilized and form longer term stable cultural patterns (Maturana & Varela, 1987; Gratier & Magnier, 2012).

Hermann

Hermann is a nine-year-old who has been learning piano via this teaching method for two years. He does not improvise much and does not request it, but seems to enjoy it when it is suggested he try it.

Like Albane, Hermann begins with a pattern that seems to refer to an attractor of its intrinsic dynamics (a three-note downward melodic march). This introductory pattern is so stable that we are inclined to think that he had practiced it before the session. The teacher validates Hermann's choice by providing harmonic support. When he finishes his march, Herman repeats the same process again. He then adopts a searching~awaiting stance. This means he plays simple patterns that enable novelty to emerge. Both partners' propositions and the pattern that they collectively shape may provide clues as to how to sustain the communication process with the creation of new information to be shared. It is a way of endeavoring to enter into diachrony with himself (with what has spontaneously been done so far), as if trying to escape its own intrinsic attractors.

The teacher then hammers chords and gradually slows down the tempo. Hermann quickly imitates him, thereby showing an interest in escaping from his appealing behaviors. This sudden adaptation shows that he was waiting for this possibility, but was unable to fulfill this desire by himself. Here, the role of the teacher is to set up interactional conditions so that the

learner can create new patterns of expression. Hermann then masters the new pattern and finishes the improvisation in perfect synchrony with the teacher, using a melodic development similar to the initial stable patterns.

The teacher asks Hermann for another improvisation, which he starts with the very same pattern again, despite repeated and explicit instructions to "do a *new* one". When one is locked in such a hyper-stable system of gestures, it is very difficult to escape and produce something new: each moment is over-determined by the past structure of the repetitive pattern. This lack of flexibility prevents the emergence of new shared and co-constructed forms. The teacher then makes suggestions by means of intense blocking actions, in order to sustain a high-level of arousal and attentive awareness of the unfolding situation. By playing something totally different, the teacher desta- bilizes coordination with the learner: everything he now plays sounds wrong in the intersubjective context. This way, Hermann can actively experience the dysfunctioning of his inescapable musical system. In short, to help and guide the search for novelty, the teacher destabilizes the learner's patterns by destabilizing their relation. The reorganization of the learner's pattern can now be catalyzed by an appealing stable pattern existing at the collective level of description. Various propositions are thus made by the teacher, until there is an abrupt (lightning) transition towards synchrony, thanks to a change in Hermann's pattern of behavior, as if he was awaiting this moment. Freed from its own attractors, he then invents a radically new rhythmic style, chang- ing his gestures and his whole-body movements. As with Albane, the escape from spontaneous achievement zones seems to fulfill core tastes, as Hermann now improvises by deploying numerous variations of his new pattern until the end of the interaction. However, the harmonic scale and the speed of his gestures does not change, and the melodic form he employs is close to his initial pattern: his tendency to express its own intrinsic dynamics is still vivid in the cooperative process. However, he is now exploring a refined and richer version of its intrinsic appealing tendencies. Using interactional techniques, the teacher opens up a range of possibilities that are continually formed in the background of the learner's dynamic signature. His individuality persists through his transformed manner of being himself and expressing that being. The individuation process entailed by this learning emerges in self-differenti- ation through interactivity. The afforded novelty now makes sense in a mutu- ally, interactively constructed and shared manner.

Tim

Tim is a 7 year-old-boy who has been learning the piano in this school for three years. He improvises frequently, first with the teacher and then

at home until the improvisation becomes a composition. He associates his improvisations with the metaphors and narrative situations he depicts by telling stories while varying his gestures in terms of type, speed or amplitude.

Once again, the learner begins with patterns that are representative of his individual technique, which he most generally bases on regularly repeated intervals. The teacher validates the propositions by joining his pulsation and speed. After this phase of synchrony, he blocks Tim's pattern, entailing a perturbation in the coordination of his limbs. Tim then lets one of his hands lead the other in a desynchronized fashion, and explores inter-limb patterns until something stable pops out: a syncopated pattern (i.e. alternating hands). He plays this pattern accelerating and decelerating as if he was experimenting and probing his own ability to stabilize it, which is mimetically validated by the teacher. Afterwards, Tim comes back to his previous rhythmical pattern. As he has acquired good mastery of the musical communicative processes over the years, Tim is now able to lead most of the improvisation until the end, while quickly adapting to the variation the teacher proposes. Despite the numerous variations he uses, Tim plays at a relatively stable tempo from beginning to end, reflecting a tendency to be attracted towards this particular range (he uses this tempo in other improvisations as well).

As exemplified when he lost between-hands synchrony, Tim has general difficulties in coordinating his own movements as well as his expressive actions to those of others (one might say that intrapersonal and interpersonal diachrony co-exist here). His spontaneous achievement zone should thus consist of small movements, with ever-changing patterns composed of scattered notes. However, he adopts a very percussive kind of gesture, with broad movements, when seeking to play synchronous notes by playing intervals or bimanual chords. These patterns differ drastically from what we would expect of his apparent intrinsic dynamics. It seems as if he is trying to overcome his coordination issues by constantly looking for synchrony, both at the individual and the collective level. His search for synchronization actually seems to constitute his core taste. The stabilization of his technique is thus an achievement zone that is not spontaneous, but has been facilitated through the interaction process, where the role of the teacher is to favor the emergence of such synchronous activities. Here, teaching is enacted in the interaction process (the teacher actively discovers Tim's issues by interacting with him) and so is learning (Tim overcomes his difficulties through improvised interaction).

Conclusion

In this paper, we have provided a perspective (based on inter-enactive and coordination dynamics approaches) for understanding teaching~learning processes. Mutual understanding, which is both a means and an end in education, is rooted in embodied collective dynamics, where the interaction process plays a constitutive role (De Jaegher et al., 2010). By appropriating and regulating the dynamics of interaction, one can modulate individual sense-making and therefore guide learning processes. In other words, the teaching~learning relation can be enacted in and through the dynamics of interaction.

The use of spontaneous improvisations in the Kaddouch pedagogy provides an illustrative example. As teacher and learner face problematic and unprecedented situations, the role of the teacher has to be enacted, actively brought forth in the interaction, through mastery of the unfolding collective dynamics that the partners embody. Learning is also enacted in these kinds of processes, both by regulating the relational dynamics and by being attracted by them.

Here, the main and complementary pedagogical techniques we called synchrony and diachrony can only be defined from a relational point of view and constitute means of enacting teaching~learning in the interaction process. By enacting phases of synchrony, the partners can be together: they can share the time and contours of their meaningful embodied experiences. It is also a means of stabilizing the relation, and thus the movements of the learner who can explore further behavioral possibilities. By destabilizing the relational dynamics so as to create a phase of diachrony, the teacher provides an opportunity for both the general learning of behavioral flexibility and the acquisition of new specific patterns of expression. Here again, the interaction process and its guidance by the teacher constitute collective dynamics that attract learners' behavioral patterns. On the other hand, the learner's motivation to communicate makes his own reorganization necessary so that coherence can be maintained at the intersubjective level. That way, new co-enacted meaning can emerge in the interaction. What is learnt is a dynamical mastery of the unfolding interactive situations, by actively participating in their organization.

The interaction process is thus potentially transformative, giving access to behavioral regions that are not available outside the interaction process: embodied collective dynamics and their regulation can thus facilitate the lightning acquisition of new skills. Of course, the analysis presented remains clinical, and coordinated learning through interaction and its stability have to be tested empirically with appropriate quantitative (dynamical)

tools, an avenue for our future work. Note, however, that by interactively probing the stability of the learners' patterns, the teacher here enacts in real situations the kind of experiments employed in laboratories to study patterns of dynamic learning (Kostrubiec et al., 2012).

In this regard, in our case-studies, the intrinsic dynamics of spontaneous achievement zones are enactively uncovered by the teacher in the interaction process, and so are core tastes. In fact, it is the distinction between the two that both teacher and learner enact interactively. Indeed, it appears that intrinsic preferences differ from core tastes and desires, though the later exploit the former by extending the phase space of potential behaviors. Furthermore, though "core tastes" seems to be a very individualistic notion, not only these core tastes emerge in the teacher~learner interactive processes (e.g. Hermann's escapement from his own routine thanks to the interaction process), but the meanings they constitute are generally also about inter-subjectivity itself (e.g., the search for Tim's synchrony, Albane dancing on her seat when resonating with the co-created music or her playful appropriation of the structure and principles of interaction). Here, individuation processes unfold in the same way shared meanings emerge: by the coordinative and self-differentiating transformative effects of inter-enaction.

Overall, intersubjective embodiment (i.e. the co-constitution of the interleaving of living bodies and their interlived experiences), by means of mutual (though asymmetrically guided, learner-centered) regulations of relational dynamics, allows for teaching and learning to be co-enacted in the interaction process itself. We hope that the above presented view and its application can provide insights for the discussion, design and improvement of broader and more diverse educational settings.

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