

Epigenetic Embodiment

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Abstract

In this short presentation we wish to formulate a definition of social embodiment grounded on an analysis of the relations between emotions, social interaction and development. Our hope is that this theoretical definition can be “tested” by social robotics, conceived in a “synthetic” (Pfeifer et al., 2008) or “constructivist” (Nehaniv and Dautenhahn, 2007) way – in short: building robotic models to comprehend human cognition.

One interest of this definition of social embodiment lies in that it expresses a “post-cognitivist” approach to cognitive science in its refusal of the “classic paradigm” that modelises the human cognitive system as a computer and cognition as computation of representational internal states (Nunez and Freeman, 1999; Calvo and Gomila, 2009). This different orientation is manifest in the very structure of our definition of social embodiment, which condenses four closely interrelated sub-theses. The first is that emotions should be conceived as salient moments in a process of social coordination (Dumouchel, 2008), rather than as internal states resulting from representational information-processing. In conformity with this first thesis, the second claims that “expression of emotions” should not be seen as a source of information concerning the internal states or intention of action of individuals, but as a social process through which the intentions of actions of agents are co-determined leading to coordination. The third thesis is that this process of emotional co-determination drives human epigenetic development – in particular cognitive development. The fourth is that this view of the role of emotional coordination in development requires a “radical embodiment” (Clark, 1999) conception of human “mind” (Damiano, 2009) that rests on a systemic definition of social embodiment, that can be expressed in the theoretical language of autopoietic biology and fits well with recent social neuroscientific insights (Gallese, 2005).

Social Emotions

What is a social species? There does not seem to be any universally agreed upon definition among biologists or ethologists. An animal for which interactions with other members of its own species are important is said to be a social animal. However this very intuitive definition is not extremely useful because it is not clear what “important” means. Furthermore there is a sense in which relations with other members of one’s species are always important at least in reproduction for organisms which reproduce sexually. We propose the following definition: a species is social to the extent that the biological advantages or disadvantages of its members depend on their interactions with other members of their own species.¹ Understood in this way, being social is a question of degree, and most animals are social, at least during some period in their life, i.e. early childhood, mating and when (and to the extent that) they raise their offspring. Strictly speaking, a social species is one where the majority of advantages that its members obtain and the majority of disadvantages they suffer result from interaction with other members of their own species. Being member of a social species is therefore to be *species dependent* in a particular way. All animals depend on other members of their species to reproduce and competition mostly takes place between members of the same species. However, the interests of individual members of a social species do not conflict and diverge only, they often also converge, and individuals can profit (and incur costs) as much from cooperation as from competition. In consequence these animals are faced with a particular problem of coordinating their behavior with other members of their species. The central claim of (Dumouchel, 2008; 1999) is that what we call emotions among humans, are aspects of an evolved mechanism that addresses this problem.²

¹ “Of their own species”: this allows for a principled distinction between being a social animal and being a parasite, as well as with symbiosis.

For the purpose of this paper it is not necessary to agree with this general thesis concerning the nature of emotions but simply to recognize that in a social context affective displays play a fundamental role in intra-specific coordination. In a social context emotions, before being motivations for action, are strategic signals (Ross and Dumouchel, 2004). Members of a social species can harm and benefit each other in very important ways; there results for each animal an uncertainty concerning the future behavior of others. Through affective expression humans try to reduce that uncertainty. Emotions are strategic signals through which we coordinate each others behavior. Affective expressions allow to steer shared relations towards cooperation or competition. Affective signals can be considered strategic because they help determine each participant's "payoff" in the "game of life". It does not however follow that they are the results of strategy on the part of individuals. However, affective displays should be considered as a form behavior in its own right, rather than as the expression of an internal state of the organism. Through such displays social animals influence each other. They properly act upon each other and transform each other's internal state. In consequence, the "emotion", considered as an internal state, comes after the expression rather than before.

Emotions should not be taken independently of the sequence of interactions that precede them and within which they intervene. The impression that emotions can be studied in isolation comes from the fact that we generally conceive emotions in the context of a single organism's relation to his environment. For example, the paradigmatic scenario for fear is usually something like a hiker who suddenly comes face to face with a snake on a mountain path. However in the context of social interactions emotions rarely happen all of a sudden, rather they take place in a history of interaction which gives them their meaning. Emotions are salient moments in a continuous process of social coordination. They are salient moments, in view of the fact that this coordination for the most part takes place at a sub-personal level. Agents are usually not aware of the way in which their affective expression both acts upon others and is

² Emotions are not the only way to resolve the problem of coordination among members of a social species. For example among social insects, as (Mead, 1934) had already noticed, the difficulty is to a large extent resolved through phenotypic differentiation of individuals.

a result of the others' affective expression. In social contexts strong emotions correspond to the moment when this ongoing process of coordination comes to the forefront of the relation.

These salient moments at times also correspond to fixed points in the process of affective coordination. Strong emotions do not only lead to strong motivations in those who experience them, they also create expectations in those who are exposed to them. These expectations should not be conceived in the form of explicit propositional contents. To say that your anger creates in me the expectation that you will become violent does not mean that I have any mental representation of your future behavior, but simply that I am afraid. My fear anticipates your violence and your anger anticipates my non-resistance. My fear satisfies your expectation and your anger sustains my expectation. In this way the system made of my fear and your anger finds an equilibrium point, which can become entrenched as a convention of coordination between us. Such equilibrium of affective coordination does not imply that the corresponding expectations are counter-factually true. That is to say, it does not imply that it is the case that if you do attack me I will not resist, nor does it imply that if I do resist you will attack me. However, once equilibrium is reached the expectations are in a sense "realized" and third parties who witness the interaction expect the agents involved to "live up", so to speak, to the expectations on which they settled.³

Emotions understood in this way are not internal states, nor are they, in themselves, strong motivations, though they can lead to them, but salient moments in a continuous process of social coordination. It is nonetheless true that changes of internal states and behavior are associated with these salient moments. It is therefore important to understand how these changes are brought about.

Against Communication

This process of social coordination through affective expression should not be conceived as a form of communication and it does not rest on the exchange of information concerning the internal states (emotions) of the organisms

³ As one of us tried to argue elsewhere, such expectations are "quasi-normative". See Dumouchel (2004).

involved. Even though adults, and robots, can infer conclusions, or “extract information” about the future actions of agents on the basis of their emotional displays, there are good empirical and theoretical reasons to believe that exchange of information plays a relatively minor role in affective coordination. Fernald (1993) and many others argue that during interaction between a caregiver and a very young infant the affective expression of the mother directly affects the nervous system of the child.⁴ Rather than carrying information about the internal state of the caregiver the affective expression of the adult directly causes the child’s affective state as a reaction.⁵ This, we claim, is not only the case with young children: even among adults the primary effect of affective displays is not to provide information, but to produce an affective reaction. We do not simply perceive the affective expressions of others, but also react affectively to them. This affective reaction is not only faster, but also much more flexible than the simple “recognition” of the expressed emotion. While the recognition of an emotion knows only one good answer and failure to correctly recognize the emotion constitutes a mistake, many different affective reactions can be appropriate when one is exposed to the same affective display. Fear, anger, surprise or even laughter can constitute appropriate responses to the other’s expression of anger.

In the case of the affective relation between a very small infant and its care-giver there are good empirical reasons to believe that affective coordination cannot rest on an exchange of information and that the process of direct influence is to some extent reciprocal.⁶

The main theoretical reason to believe that the process of social coordination does not rest on the exchange of information is because the relevant information does not actually exist before affective coordination is achieved. In its most general form social coordination can be described as that of coordinating one’s intention of action towards another agent with that agent’s intention of action towards us. As de Wall and Aureli (1999) pointed out, the main difficulty

⁴ Meany M.J. et al. (1996).

⁵ See also Desjardins and Fernald (2008) on the effect of social interactions on brain structure in various species.

⁶ Recent research on *mirror neurons* and other *mirroring mechanisms* suggest ways in which this reciprocal direct influence could be achieved among humans and other primates.

involved in doing this lays in the fact that an agent’s intention of action towards another is not independent of the other’s intention of action towards the first.⁷ Since this is true of both agents, it is clear that the goal of affective displays cannot be to exchange information which does not yet exist concerning one’s intention of action towards the other. Rather just as in the case of mother and young infant, adult agents mutually determine each other’s attitude towards each other through a continuous process of affective expression.

This process of mutual influence mainly takes place at a sub-conscious, sub-personal level. We are unaware of it most of the time and it usually only becomes conscious during those salient moments which we call “emotions”. Nonetheless it is clear that affective expression is continuous. Only androids and dead people can have a perfectly neutral expression,⁸ each and every one of us is always either happy, sad, busy, relaxed, “not to be bothered with”, engaging, serious, anxious, ridiculous, and so on. There is no affective silence. Even though all of the above terms refer to different states or attitudes which a person can have, inasmuch as they are expressed their effect is to act upon others. It is, for example, to “drive them up the wall”, to make them feel at ease, to chase or attract them. Unlike “emotions” affective coordination is not something which has a beginning and an end, it is an ongoing process. Through this process we mutually co-determine each other’s intention of action towards each other. This entails that human beings do not determine independently, autonomously, (at least some of) their most important intentions of action. What explains why this is so is that they are social animals who radically depend upon each other.

Development and social interaction

A central aspect of development in humans and many animals is the extent to which the organism changes. To mature, to become able to do and learn new things is inseparable from

⁷ It can be argued that in human societies this problem of uncertainty is to a large extent resolved through social codes of behavior. This is true, but affective coordination is a mechanism that functions in real time and that can always overrule the injunctions of social codes: we get angry or fall in love *when we should not!*

⁸ Hiroshi Ishiguro suggests that the reason of the “uncanny valley” may be that interacting with an android is a bit like interacting with a dead person (personal communication).

becoming physically different. Development entails ontogenesis and is equivalent to a transformation of embodiment. This change in embodiment among humans comes together with a profound revolution in the way a person participates in social relations and coordination. This corresponds to the fact that the individual becomes less dependent, and simultaneously a more dangerous competitor and a collaborator of greater value. In this section we wish to argue that social interactions drive development and that affective coordination is the main element in the transformation of a helpless organism into a relatively autonomous agent. The mechanism through which agent's intentions of actions towards each other are co-determined, and that bears witness to their radical interdependency, is also the means through which they become, to some extent, autonomous.

As mentioned earlier the relation between a very young infant and its caregiver is probably where social coordination through the co-determination of affective states can be most clearly seen. As development proceeds the influence of the affective displays of a person on others becomes more and more hidden from view. However it does not disappear. It continues together with other forms of coordination and is integrated in explicit communication between agents. For example, affective expression remains a fundamental aspect of spoken language that is easily recognizable in differences of pitch, speed and volume of speech. We say things to each other and the response we receive does not only depend on the semantic content of what is said but also on how it was said. The main difference between a very young infant and an older child or adult is the development of mind, which allows us, for example, to understand language. However a person's "mind" is also often moved, in ways it does not understand, by the affective expression of others.

A very young infant has a very limited repertoire of action. He or she can only do little, but from the early beginning of its life a child is able to either accept or refuse to interact. It is a fundamental social action. Small and helpless as the child is, this response has a strong influence on the caregiver's actions and attitude towards the child. As time goes by the child and caregiver's relation gets populated with objects of joint attention that can either be physical objects or situations. The infant learns to interact not only with another co-specific, but also to

interact together, but not necessarily in agreement, in relation to various objects. Hobson (2002) argues that a child develops a mind through discovering that the adult's attitude towards a given object can be different from the child's. In consequence the child can acquire the ability to simultaneously entertain multiple attitudes towards the same object. The underlying idea is that having a mind, in the sense of being able to think, requires, at least, to be able to adopt various stances towards the same object, rather than to be immediately determined by it. According to Hobson a child develops this ability through social interactions. In order for this to be possible, two conditions are necessary. First the child must have a specific attitude towards an object or situation. Two the infant needs to discover that it is possible to adopt a different attitude. Studies on imitation reveal children's (and adult's) tendency to reproduce the attitude of their partners in relation. That is to say the child will reach out for or reject what the adult rejects or reaches out for. These studies like many others reveal that a co-specific's behavior can have a direct effect on the attitude or behavior of the child. This however is a tendency rather than straight mimicry, so that the child (or adult) is often torn between two different attitudes. It is this phenomena resulting from social interaction which, according to Hobson (2002), allows the child to develop a variety of attitudes towards the same object.

Therefore the co-determination of the child's attitude by others gives him or her not only a series of different attitudes, but also the distance needed to allow for choice. Mind, understood in this way, is a fundamentally social attribute. It does not correspond to any specific characteristic of an isolated individual. Individual development is a result of social interaction.

Social Embodiment

The three hypotheses we proposed so far suggest a profound shift not only in relation to *classic*, but also to *embodied cognitive science*. Our proposal requires a conception of the embodiment that goes beyond "mainstream embodiment", what Clark (1999) calls "simple embodiment", which merely adds bodily and environmental constraints to a cognitive system and which in consequence remains essentially conforms to the classical computationalist paradigm. Our approach is closer to "radical

embodiment” (Clark, 1999; Thompson and Varela, 2001; Damiano, 2009), which, conceiving mind as emerging from the materiality of the body, abandons reference to the classical computer paradigm and proposes new concepts and parameters to define cognition. In this approach not only are traditional notions of internal representation and computation considered “inadequate and unnecessary”, but the “classical decomposition” of the cognitive domain in objects (primarily: brain, body, environment) is re-drawn. Radical embodiment tends to describe mind as a structures of coupling which interconnects brain(s), body(ies) and environment(s).

In line with this second view the description of socio-emotional interaction previously presented entails that the relevant unit for understanding development should not be conceived as an individual cognitive system that receives information from outside, and, after computation, produces a representation of the appropriate state of affairs. The cognitive unit relevant to our earlier description exceeds intra-individual space, and is not characterized by informational or representational processes. Our characterization of affective interaction entails that the agents involved are not independent. Unlike classical cognitive agents they are not entirely pre-defined systems, but evolve and change during the relation. It is through relation that agents acquire definite emotions and intentions of actions; through a dynamic process that recursively re-defines them in a coupled way. The process does not rest on the exchange of information, but on the direct action⁹ of each upon the other through ongoing mutual affective display. This dynamic could be described as *embodied co-determination*: an inter-subjective cognitive process in which perception of the affective display of the other modifies the state of the nervous system of the first and vice versa. In this type of cognitive interaction the entities that interact are not entirely pre-determined from the offset, rather as the relation develops coordinated emotions and intentions co-emerge. The reciprocity of influence between the two agents involved implies that neither entirely controls this mutual transformation. The real agent of socio-emotional coordination has to be found in the relations between self and other. In fact, it is better to conceive of affective exchange

⁹ The “direct action” of one system upon the other does not imply that it controls the other, but simply means to convey that this action takes place without the intermediary of either representation of information.

as a system in its own right. This is a hypothesis which we developed elsewhere. Dumouchel (1999; 2008) argues that the “body” of emotions is not individual but social and Damiano (2009) develops a model of self-organization that interprets inter-subjective cognitive interactions as the locus of emergence of transitory inter-individual unities. These theses express at the interindividual level the post-cognitivist thesis of the “extended mind” following which the proper unit for analyzing cognition is neither the brain nor the organism but the system made of the organism and environment (Clark and Chalmers, 1998; Chiel and Beer, 1997; Wilson, 2002; Pfeifer et al., 2007; Ziemke, 2003)

In consequence, our hypothesis is not entirely speculative. It is at least possible to suggest some biological mechanisms that can underlie this type of non representational, non informational coordination. For example, Dumouchel (2006) on the basis of a comparison between emotions and biological modules identified a class of mechanism that are implemented at the sub-personal level but whose consequences (effect) become visible at the level of entire populations. Rizzolatti et al. (2002) argued that mirror neurons transgress the distinction between what is intra-individual and what is inter-individual. According to Gallese, (2005) these mechanisms which “attune” the action intention, emotion, bodily sensations of interacting individuals at a sub-personal level and allow us to conceive interactions able to structure and define the agents they relate. As Damiano (2009) argues, neuro-physiological literature concerning *mirror neurons* and other *mirroring mechanisms* in monkeys and humans supports the idea of an inter-individual dynamics that coordinates brains, bodies and environment(s) of interacting individual and, in the process co-defines them.

It is on the basis of this view of mind and socio-emotional developmental interaction that we propose a definition of social embodiment – a “radical embodiment” definition of social embodiment. We will begin from the interesting definition of embodiment proposed by Dautenhahn, Ogden and Quick (2002) in the context of robotics. This definition tries to cash in on the idea that embodiment is structural coupling with environment (Ziemke, 2003). Dautenhahn et al. characterize embodiment as the minimal condition (necessary and sufficient?) of structural coupling as conceptualized in autopoietic cognitive biology

(Maturana and Varela, 1973) has been strongly criticized by Riegler (2002) and Ziemke (2003) who consider it “an insufficient characterization”, because “every system is in one sense or another structurally coupled to its environment”. Therefore “this definition of embodiment does not distinguish between cognitive and non cognitive systems” (Ziemke, 2003:1306). It seems to us that the real difficulty of this definition is that it fails to formulate correctly the idea of structural coupling as understood by Maturana and Varela.

According to our authors:

Df1: embodiment (Dautenhahn et al.)

*A system **S** is embodied in an environment **E** if perturbatory channels exist between the two. That is, **S** is embodied in **E** if for every time **t** at which both **S** and **E** exist, some subset of **E**'s possible states with respect to **S** have the capacity to perturb **S**'s state, all and some subset of **S**'s possible states with respect to **E** have the capacity to perturb **E**'s state.¹⁰*

However, according to Maturana and Varela, structural coupling is not limited to the fact that states of the environment can perturb states of the system and vice versa. Rather there is structural coupling when the following circumstances are satisfied.

Two (or more) autopoietic unities can undergo coupled ontogenies when their interactions take on a recurrent or more stable nature.... The result will be a history of mutual congruent structural changes as long as the autopoietic unity and its containing environment do not disintegrate: there will be structural coupling.¹¹

Structural coupling refers to dynamic interaction between two systems **S1** and **S2** that gives rise to a shared history of transformation, where the actions (reactions) of one trigger, but do not control, the reactions (actions) of the other. Each system's reactions are its endogenous compensations to the perturbations that the other system's reactions constitute. As clearly outlined by many authors (Varela, 1979; Thompson, 2007, Damiano and Luisi, 2009) structural coupling corresponds to a unit of co-transformation in which the organism and its environment (two systems) become co-dependent. The self-regulatory compensations of

each constitute for the other perturbations that, in turn, trigger transformations of the internal dynamics of the first. In order for structural coupling to exist, it is not enough for one system to receive perturbation from another and vice versa, it must also be the case that these perturbations give rise in one to self-regulatory compensations that become sources of self-regulatory compensation for the other. Furthermore this interaction must become recurrent, leading to a shared history or coupled ontogenies. Therefore we propose the following definition.

Df2: embodiment of a system in an environment
*A system **S** is embodied in an environment **E** if (i) perturbatory channels exist between **S** and **E** through which each can trigger and modulate the self-regulation (autonomous activity of self-definition) of the other and if (ii) each has sufficient structural plasticity to respond to others's perturbation through its self-regulation activity*

Df1 and **Df2** are actually quite different, as can be seen in relation, for example, to... a robot. According to **Df2** a robot is embodied in an environment, not only if its sensors allow it to receive perturbations from that environment, it must also have a repertoire of sensory-motor reactions to these perturbations *that reflects its own internal self-regulatory dynamics.*

Following Dautenhahn et al.'s lead we can transform this definition of embodiment in a definition of social embodiment.

Df3: social embodiment

*Two systems **S1** and **S2** are socially embodied if (i) perturbatory channels exist between them and (ii) each of them has sufficient structural plasticity to generate a relation of co-dependence and co-specification of their self-regulating dynamics that (a) defines **S1** and **S2** as agents structurally coupled in their respective coupling with an environment and (b) defines an inter-individual unit (**S1** and **S2**) that is coupled or embodied in the environment (Cf Df 2).*

As this definition shows, there is no such thing as an individual isolated system that is socially embedded in a “social environment”. Social embodiment does not simply entail, but is structural coupling between two or more systems. This definition conveys that to be a social creature is to be dependent on other

¹⁰ Dautenhahn, Ogden and Quick, 2002, p. 400.

¹¹ Maturana and Varela (1987), p. 75.

similar system(s) in a very particular way. It can be understood as repeating in a different way what was said in the first section concerning the nature of social species and animals.

Social Robotics

If this analysis of emotions and social embodiment is correct, what does it mean to build a social robot (Cañamero, 2008)? What kind of creature, machine, agent, would such an artifact be? This paper argued that individuals are social to the extent that they are radically co-dependant. However this co-dependency, unlike symbiosis for example, does not exclude the autonomy or negate the individuality of the co-dependant agents. To the contrary, affective exchange was described as a mechanism of coordination among co-dependant systems that can lead to the emergence of autonomous agents. Furthermore we argued that embodiment is essentially social, to have a body is to be a partner in a relation.

To build a social robot then is to build a robot that is radically dependant on others (humans or other robots); a robot that also is, or can become, a pole of initiative in its relations with others. Such a robot would need to be an agent that can suffer damages if it fails to coordinate its action with those of others and who can gain advantages if it succeeds. Can this be done? The difficulty is to define these advantages and disadvantages and to determine a currency in which they can be measured or at least cashed out. One problem is that among us the accounting of gains and damages is finally made by natural selection. However, reproduction and survival do not constitute the *measure* with which individuals judge their success or failure. In fact, our co-dependency is directly located at the level of our motivational system. This means that the measure of individuals' gains and disadvantage cannot be given beforehand. Ultimately, it must emerge in and from the interaction of the robot with others, just as it does among us. Thus the goal cannot be to build a robot that "values" coordination with other, at least, not if it is going to be social in the way that we are. We humans do not particularly value coordination with others. It seems that some people never value it and it is certain that all people do not value it at least some of the time. Rather the point is that what we value is determined through our interaction with others and this is precisely what coordination means.

However, what we value however is not simply determined by others, but emerges through interaction with them. In consequence not only should a social robot's goals and objective be determined through its relations with other social agents, but it should also be case that the robot co-determines the goal and intentions of others.

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