Social Situatedness: Vygotsky and Beyond

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Abstract

The concept of 'social situatedness', i.e. the idea that the development of individual intelligence requires a social (and cultural) embedding, has recently received much attention in cognitive science and artificial intelligence research. The work of Lev Vygotsky who put forward this view already in the 1920s has influenced the discussion to some degree, but still remains far from well known. This paper therefore aims to give an overview of his cognitive development theory and discuss its relation to more recent work in primatology and socially situated artificial intelligence, in particular humanoid robotics.

1. Introduction

The concept of situatedness has since the mid-1980s been used extensively in the cognitive science and AI literature, in terms such as 'Situated Action' (Suchman, 1987), 'Situated Learning' (e.g. Lave, 1991), 'Situated Cognition' (e.g. Clancey, 1997; Kirshner & Whitson, 1997), 'Situated AI' (e.g. Husbands *et al*., 1993), 'Situated Robotics' (e.g. Hallam & Malcolm, 1994), 'Situated Activity' (e.g. Hendriks-Jansen, 1996), and 'Situated Translation' (Risku, in press). Roughly speaking, the characterisation of an agent as 'situated' is usually intended to mean that its behaviour and cognitive processes first and foremost are the outcome of a close coupling between agent and environment. Hence, situatedness is nowadays by many cognitive scientists and AI researchers considered a *conditio sine qua non* for any form of 'true' intelligence, natural or artificial.

As some of the above terms indicate, the term 'situated' is indeed commonly applied to both natural and artificial systems. The differences between the two types of systems may also help to clarify what is meant by 'social situatedness'. Brooks (1991), one of the main proponents of the situated approach within AI, formulated a number of shortcomings of traditional AI and initially particularly focused on the challenges of getting robots to act in the real world. His mobile robots were closely coupled to the *physical* environment they interacted with and therefore could be considered to be *physically situated*. However, more recently it has also been pointed out that humans are not only physically, but also socially and culturally situated (throughout the rest of the paper we will refer to both social and cultural aspects under the label 'social situatedness'). This is also reflected in an increasing interest in socially situated AI (e.g. Brooks & Stein, 1994; Brooks *et al*., 1998; Dautenhahn, 1995; Edmonds, 1998; Kozima, 2000). Dautenhahn *et al.* (in press), for example, explain the term as follows: "a *socially situated* agent acquires information about the social as well as the physical domain through its surrounding environment, and its interactions with the environment may include the physical as well as the social world".

While the interest in social situatedness is relatively new in cognitive science and AI, the Russian scholar Lev Vygotsky has pointed out the importance of social interactions for the development of individual intelligence already during the 1920-1930s. Vygotsky's work has influenced theories of (socially) situated cognition to some degree (e.g. Clark, 1997; Hutchins, 1995; Kirshner & Whitson, 1997), but it still seems to be far from well-known. Hendriks-Jansen (1996), Brooks *et al.* (1998), and Sinha (2001) for example, discuss many ideas closely related to Vygotsky's work without actually referring to it at all. As Scassellati (2000) pointed out, research in (human) cognitive development and research in situated AI and robotics can and should be complementary, but unfortunately comparative analysis of ideas and theories from different disciplines is still largely lacking. This paper therefore presents Vygotsky's ideas in quite some detail and evaluates them in the light of recent work in primatology and socially situated artificial intelligence, in particular humanoid robotics.

2. Vygotsky and Beyond

While the interest in the social embedding of individual intelligence has increased rapidly within contemporary cognitive science and AI, and much of the literature is, directly or indirectly, clearly influenced by Vygotsky, there are surprisingly few researchers who actually mention his work as a source of inspiration. Moreover, some of them seem not to have a full understanding of Vygotsky's theory and basic ideas, but instead only pick out selected parts to fit their own purposes. The following subsection therefore presents an overview of Vygotsky's theory of cognitive development and elaborates in particular those aspects most relevant to the discussion in this paper. Subsections 2.2 and 2.3 then evaluate his views on animal intelligence in the light of recent primate studies and address a number of criticisms of his work respectively.

2.1 Vygotsky's Cognitive Development Theory

Vygotsky (1978) distinguished between *elementary* and *higher* mental functions. He argued that our elementary mental functions had to be those functions that were genetically inherited and existed both in humans and other animals. These elementary (at times called natural) mental functions are, for example, elementary memory, perception and attention. These are controlled by the recognition of co-occurring stimuli in the environment, which Vygotsky (1978) referred to as *signalisation.* The higher (sometimes called cultural) mental functions are, according to Vygotsky, *exclusively human* and emerge dynamically through radical transformations of the lower ones.

In elementary functions there is a direct link between a stimulus in the environment and a response from the organism, which Vygotsky (1978) expressed by a stimuli→ response formula. However, for a higher mental function the structure differs significantly, since it entails an *intermediate link* between the stimulus and the response, as illustrated in figure 1.

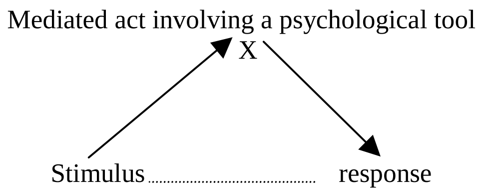

Figure 1: The organisation of higher behaviour via a mediated act. Adapted from Vygotsky (1978, p. 40).

Vygotsky (1978) declared that this type of organisation is fundamental to all higher cognitive processes, although typically in a much more complicated structure than illustrated above. The intermediate link involves an arbitrary sign (nowadays referred as a psychological tool) which is 'drawn into' the cognitive operation to fulfill a special function, creating an altered relation between stimulus and response. This sign also possesses the important characteristic of reverse action (that is, it operates on the individual, not on the environment). Psychological tools function as internally oriented, since they transform natural human abilities and skills into higher mental functions. Actions conducted with these psychological tools, create thoughts. In 1933 Vygotsky therefore declared that "the central fact about our psychology is the fact of mediation" (Vygotsky, 1982, p. 166, quoted from Wertsch, 1985, p. 15).

These psychological tools bridge the gap between elementary and higher mental functions, and of the psychological tools mediating our thoughts, feelings and behaviour, language is the most significant. Vygotsky (1962, 1978) declared that the primary function of language, in the form of speech, is a device for social contact, and interpersonal communication, influencing other people, since "the child begins to master his surroundings with the help of speech" (Vygotsky, 1978, p. 25). Later, this social speech transforms and becomes *egocentric speech,* which internalises social speech for the child's own ends.

Vygotsky (1962) argued that this egocentric speech is a shift from social speech (between people) to inner speech, which 'goes' inward into the mind, by directing our own thinking. Consequently, the interpersonal becomes intrapersonal, and 'actions' with this special psychological tool create thought, thus language liberates us from our immediate perceptual experience and allows us to also represent the past, the future and the un-present. Thinking and language are dynamically related, since understanding and producing language are processes that transform the process of thinking.

Moreover, Vygotsky (1978) identified two different lines of cognitive development, influenced by *biological* and *sociohistorical factors*. The *biological* factors are part of our ontogenetic development, and incorporate the development of the central nervous system, physical growth and maturation. These biological factors control the early months of life in humans, responsible for the development of perception, simple memory and involuntary attention. Vygotsky called the emergence of these elementary mental functions *natural (or primitive) development.* The second line of development is *sociohistorical*, and it is embarked on with the invention and use of culturally based psychological tools (which Vygotsky referred to as *signification*) in primitive humans. These tools function as 'regulators' of human *social* behaviour.

> *The growth of the normal child into civilization usually involves a fusion with the processes of organic maturation. Both planes of development – the natural and the cultural – coincide and mingle with each other. The two lines of change interpenetrate one another and essentially form a single line of sociobiological formation of the child's personality.* (Vygotsky 1960, p. 17, quoted from Wertsch, 1985, p. 41).

Hence, the cognitive abilities of an ‘enculturated’ adult human are the product of these processes of cognitive development, in which ‘primitive’ humans are transformed into cultural ones. The major goal of Vygotsky’s research was to explain these qualitative changes by identifying the influence of the different factors in this *transformation process*. Roughly speaking, the child initially has to learn the particular psychological tools in its culture, and then learns how to use them to master and control its own behaviour. This transformation process, from elementary (or natural) mental functions to more complex higher functions is described (not explained) by two key principles, namely, the process of *signification* (using psychological tools), and a principle referred to as the *General Law of Cultural Development (*Wertsch, 1985). The essence of the latter is as follows:

> Every function in the child’s development appears twice: first, on the social level, and later, on the individual level; first, *between* people (*interpsychological),* and then *inside* the child (*intrapsychological)* … All the higher functions originate as actual relations between human individuals…*The transformation of an interpersonal process into an intrapersonal one is the result of a long series of developmental events.* …The internalisation of socially rooted and historically developed activities is the distinguishing feature of human activity, the basis of the qualitative leap from animal to human psychology. (Vygotsky, 1978, p. 56-57, original emphases)

Vygotsky (1978) called this process of transforming an interpersonal process (human-to-human interaction) into an intrapersonal one *internalisation.* To explain the essential role of social interactions during this transformation process he used the example of the development of pointing in the child. He claimed that initially it is only a simple and incomplete grasping movement directed towards a desired object, only represented by the child’s reaching and grasping movement, and nothing more. When the caretaker comes to help the child, the meaning of the gesture situation itself changes, since it obtains another meaning, as the child’s failed reaching attempt provokes a reaction, not from the desired object, but from another person. The individual gesture ‘in itself’ becomes a gesture ‘for-others’. The caretaker in this case interprets the child’s grasping/reaching movement as a kind of pointing gesture, resulting in a socially meaningful communicative act, whereas the child itself at that moment is not aware of its communication ability. However, after a while the child becomes aware of the communicative function of its movements, and then begins addressing its gestures towards other people, rather than the object of interest that was its primary focus initially. Thus, “[*t]he grasping movement changes to the act of pointing”* (ibid. p 56). As Kozulin (1986) pointed out, it is essential to note that the child itself is the last person who ‘consciously’ grasps the ‘new’ meaning of its own pointing gesture.

Another central concept in Vygotsky’s theory is the so-called *zone of proximal development*. It is in the zone of proximal development that the child learns, through social interactions, how to use the tools available, especially the psychological ones. Vygotsky (1962, 1978) noticed that when a parent or another person gives meaning to the child’s interaction, when it is unable to do so for itself, the child is working in the zone of proximal development. Vygotsky characterised the *zone of proximal development* as follows:

> *It is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers. (*Vygotsky, 1978, p. 86, original emphasis)

The assisting person realises the child’s achievement by means of clues, hints, explanations, joint participation, encouragement, regulating and controlling the child’s focus of attention and so on. Vygotsky (1978) also related *imitation* and *learning* to the zone of proximal development. He argued that a child merely can imitate what is within its zone of proximal development, and if a caregiver presents a too advanced solution to a problem, the child could not grasp the solution, even if the solution was presented repeatedly. The child can therefore only ‘imitate’ and adopt a solution to a problem or an activity if it is within the boundaries of the child’s particular zone of proximal development. Moreover, Vygotsky (1978) argued that only humans possess a zone of proximal development:

> A primate can learn a great deal through training by using its mechanical and mental skills, but it cannot be made more intelligent, that is, it cannot be taught to solve a variety of more advanced problems independently. For this reason animals are incapable of learning in the human sense of the term; *human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them.* (Vygotsky, 1978, p. 88, original emphasis).

Thus, according to Vygotsky, the ‘minds’ of chimpanzees, for example, can never be developed and extended further than their biological heritage, since they lack a zone of proximal development. However, the following subsection will address evidence from recent primate studies that indicate the opposite.

2.2 Primate Studies

Contrary to Vygotsky's theory, recent findings especially in great apes indicate that humans are not the only ones performing acts of internalisation. Tomasello (1999) pointed out that chimpanzees raised by humans (so-called 'enculturated apes') become to some extent situated in the human socio-cultural environment. Furthermore, they can acquire some human-like social behaviours and mechanisms that they actually do not develop in the wild. Taylor Parker and McKinney (1999) pointed out that imitation actually occurs even in wild chimpanzees and is not only a result of 'enculturation' by humans. However, the presence of a human cultural environment makes it possible for the apes to go beyond their current level of ape performance and become more 'human-like' through social interactions and scaffolding.

One of the most famous enculturated apes is the bonobo (or pygmy chimpanzee) *Kanzi* who has learned to communicate via symbols representing words and is able to use about 240 signs (Savage-Rumbaugh *et al.*, 1998). Initially, the major goal was to teach Kanzi's mother how to use symbols (in the form of lexigrams) to communicate her desires and needs. At the time Kanzi was so young that he did not want to be separated from his mother during her training sessions so he was present too. After a while Kanzi showed that he had acquired a communication ability, without explicitly having been trained, and actually performed much better than his mother. Kanzi's language comprehension has been argued to be as good as that of a two-and-a-half-year-old human child and he is also able to interpret spoken sentences, even when hearing them for the very first time (Savage-Rumbaugh *et al.*, 1998).

Furthermore, some enculturated apes, such as Kanzi, are able to perform pointing gestures, but there is no scientific evidence that chimpanzees really point in the wild (cf. Povinelli *et al.*, 2000). Instead, their pointing seems to be the outcome of close social interactions with human beings, since they probably have observed how people use the pointing gesture in interactions with each other and also towards the ape.

2.3 (Other) Criticisms of Vygotsky's Work

Various forms of criticism have been raised against Vygotsky's work, especially that he did not pay enough attention to the biological factors in his work, particularly in his empirical research. According to Davydov and Radzikhovskii (1985), there is a major gulf between 'Vygotsky the psychologist' and 'Vygotsky the methodologist'. They pointed out that Vygotsky almost exclusively focused on the socio-cultural forces in his empirical studies, and that he neglected the biological line of development, especially the physical maturation in the child during its first years of life. They further argued that Vygotsky tended to view the biological factors as 'raw materials', which then were transformed by the socio-cultural forces, whereas he mentioned almost nothing about how changes in the biological factors may influence the socio-cultural ones. On the other hand, Wertsch (1985) pointed out that Vygotsky himself was aware of the necessary, but not sufficient, conditions provided by the biological factors, since he assumed that the natural factors play the major role in early ontogeny, and that the cultural forces take the leading role later on. Hence, Wertsch (1985) argued that Vygotsky did not view advanced cognition and thinking as the outcome of social factors alone, but he also stated that "culture creates nothing; it only alters natural data in conformity with human goals" (Vygotsky, 1960, p. 200, cited in Wertsch, 1985).

Another criticism is that Vygotsky only managed to accomplish a broad outline, with very few details. This is partly explained by the fact that Vygotsky died of tuberculosis at the age of 37, before he had developed a complete theory (Wertsch, 1985). However, the main contribution of his theory is the claim that our advanced cognitive abilities emerge as a result of a prolonged ontogenetical period (*epigenesis*), in which our biological factors become shaped and constrained through social interactions in our particular culture. Vygotsky's most important and unique claim is that these cognitive processes only can be understood if we actually understand the arbitrary stimuli and sign systems (psychological tools) that mediate them (Wertsch, 1985). Vygotsky's explanation of mental processes is heavily dependent on the forms of mediation involved, thus offering a 'wider' explanation of human cognition than classical cognitive science.

3. Socially Situated AI

Vygotsky's theory of cognitive development particularly stresses that individual intelligence emerges as a result of biological factors (embodiment, one might say in today's terms) that actively participate in a physical and particularly a social environment (in today's terms: situatedness) through a developmental process. Interestingly, some AI researchers (cf. Brooks *et al*., 1998; Kozima, 2000; Zlatev, 2001) present a closely related argument: If a humanoid (i.e. physically human-like) robot 'grew up' in close social contact with human caregivers then it might develop similar cognitive abilities as human beings, i.e. in some sense become an 'enculturated' robot.

Since approximately the mid-1990s a number of researchers in situated AI and robotics have begun to take seriously the idea that the creation of artificially intelligent systems might require not only physical situatedness and embodiment, but also some form of child-like development in interaction with some social environment. We can roughly distinguish between projects that investigate scenarios in which that social environment consists of humans, e.g. robots socially situated through interaction with human 'caregivers', and projects investigating robot-robot interaction, e.g. robots (or simulated agents) learning through imitation of other more experienced or skilled agents (e.g. Billard & Dautenhahn, 1997, 1998, 1999; Billard *et al.*, 1998; Dautenhahn, 1995; Edmonds, 1998). We here focus on the former type, i.e. human-robot interaction, since the inspiration from and relation to Vygotsky's ideas is particularly clear in some of these projects.

One of the insights (re-) gained by recent research in embodied cognition (e.g. Lakoff & Johnson, 1980, 1999; Varela *et al.*, 1991; Clark, 1997; Pfeifer & Scheier, 1999) is that the mind is in fact not largely independent of the body, but in fact strongly determined by it. For AI research striving to model human intelligence this has radical consequences. Clearly, if cognition is dependent on body and sensorimotor capacities, then the only way to achieve or study truly human-like intelligence in artefacts is to equip them with human-like bodies and sensorimotor capacities, i.e. to build *humanoid robots*.

There are by now a number of projects which have taken this approach, such as Brooks' well-known *Cog* project (Brooks *et al.*, 1998) or Kozima's *Infanoid* project (e.g. Kozima & Yano, 2001). Both Cog and the Infanoid are upper-torso humanoids, i.e. roughly human-size robotic torsos equipped with stereo-vision heads, arms and hands with degrees of freedom roughly similar to those of human bodies. However, obviously this only solves part of the problem. Even if a human-like body nowadays by many is considered a *necessary* condition for a human-like mind, it could hardly be a *sufficient* one. The remaining question is, roughly speaking, how to get a mind 'into' the body. Both of the above projects, inspired to some degree by Vygotsky's theories, aim to let their robots undergo some kind of *artificial ontogenesis* in physical and social interaction with their environment. Both also particularly emphasize the interaction with human caregivers, based on theories of social learning in infants. That means, Cog and Infanoid are supposed to acquire or develop sensorimotor and cognitive capacities, and ultimately a mind, in some kind of long-term interaction similar to the ontogenesis of human children (note, however, that it is only the software, not the hardware/body, which develops).

Taking this approach to the extreme, one might argue like Zlatev (2001, p. 155) that such "robotogenesis could possibly recapitulate [human] ontogenesis, leading to the emergence of intentionality, consciousness and meaning" in robots. He further argues that there is "no good reason to assume that intentionality is an exclusively biological property … and thus a robot with bodily structures, interaction patterns and development similar to those of human beings would constitute a system possibly capable of meaning" (ibid).

This view is closely related to Harnad's (1989, 1990) formulation of a *robotic functionalism*, partly a response to Searle's (1980) famous *Chinese Room Argument* (CRA). The CRA was directed against what Searle referred to as "strong AI", i.e. roughly speaking the view that computer programs could be (or have) actual minds rather than just useful tools for the modeling of mind (the latter he referred to as "weak AI"). In particular Searle argued that computer programs simply lacked a number of "causal powers", including perception, action and learning, which, according to him, would be necessary for intentionality (or intrinsic meaning, in Harnad's (1990) terms). Hence, one might argue, as Zlatev (2001) does, that a sufficiently human-like robot, equipped with some artificial equivalents of those causal powers (perception, action and learning), could very well have or develop a mind in the same sense as humans.

Zlatev's elaborate proposal for the development of a robot mind, fairly close to the ideas underlying both Infanoid and Cog project, is based on the following cornerstones:

- sociocultural situatedness: the ability to engage in acts of communication and participate in social practices and 'language games' within a community;
- naturalistic embodiment: the possession of bodily structures giving adequate causal support for the above, e.g. organs of perception and motor activity, systems of motivation, memory and learning; …
- epigenetic development: the development of physical, social, linguistic skills along a progression of levels so that level n+1 competence results from level n competence coupled with the physical and social environment. (Zlatev, 2001, p. 161)

It should be noted that both Cog and Infanoid project are far from having fully implemented visions as ambitious as the above. The *Cog* project has started by implementing the following basic social behaviours: pointing to a visual target, recognizing a beginning to joint attention through face and eye finding, imitation of head nods and regulating interaction of expressive feedback (Brooks *et al.*, 1998). Furthermore, the vision and emotive response platform *Kismet*, developed in the same lab, can engage in various forms of basic interaction behaviours, grounded in a 'drive system' (*fatigue*, *social* and *stimulation)*. The platform's 'mood' becomes replicated as emotional and facial expressions (*anger*, *calm*, *disgust*, *happiness*, *interest*, *sadness* and *surprise)*. As a consequence of not being stimulated the system 'expresses' *boredom*, while overstimulated it 'expresses' *fear*, otherwise Kismet 'is' *interested* (Breazeal & Scassellati, 2000). Finally, in *Infanoid* the initiation of a shared attention ability has been implemented so far, namely the capability of detecting human faces and finding their eyes, then catching the gaze direction in order to find the object of interest (Kozima, 2000).

4. Discussion and Conclusions

As mentioned in the introduction, this paper aims to overview and integrate different perspectives on the role of social situatedness in the development of (individual) intelligence. We started off by providing a summary of Vygotsky's cognitive development theory, which, directly or indirectly, has had a very strong impact on today's research. Many aspects of Vygotsky's work have been criticised and some positions have turned out to be wrong. However, considering its 'age', many elements of Vygotsky's theory are surprisingly up-to-date and in line with contemporary research. In particular the central points of his theory, the view of social scaffolding as a necessary requirement for the development of individual intelligence, and more specifically the observation that "[e]very function in the child's development appears twice: first, on the social level, and later, on the individual level", are still cornerstones of current theories, and not least also of current work on socially situated AI.

Vygotsky himself considered socially situated development of intelligence as limited to human beings. In particular he did not believe that any other animals had what he referred to as the zone of proximal development. Recent work in primatology certainly can be considered to prove him wrong in this particular point. There are striking similarities to Vygotsky's 'general law of cultural development' in Kanzi. For example, his 'cognitive' development appeared twice, first between agents (his mother and her trainers) and then on the individual level (in Kanzi himself). His training begun when he was a youngster, and not a grown up, resulting in an ontogenetic development that was a combination between biological and social factors that Vygotsky argued would be significant for the development of individual intelligence. This is quite interesting, since Vygotsky initially tried to identify the difference in the intelligence of humans and other animals, arguing that the latter could not be 'taught' to be more intelligent. Thus, instead of characterising the uniqueness of human intelligence, the 'Vygotskyan' approach actually 'blurs the line' between animal and human intelligence.

Studies of socially situated animal intelligence may contribute much more to cognitive science and AI than they have done so far. Despite a lot of research on human infants, there is not yet any clear understanding of how the developmental process emerges, partly due to the fact that it progresses so quickly in human beings, with the result that it is very hard to observe what exactly happens. In non-human primates, however these processes develop more slowly and therefore they are easier to study (on the other hand, they might be more difficult to interpret and observe, at least in the wild).

But it should also be noted that there are some tentative risks in combining different research areas. One risk might be misinterpretations of other fields, and another lies in significantly different definitions of the same concepts. One example is the use of the concept of *imitation*. AI researchers (cf. Brooks *et al.*, 1998; Billard and Dautenhahn, 1997, 1998) tend to interpret the term imitation in a relatively wide sense, whereas primatologists are much more restrictive, arguing that imitation is *the* most advanced social learning mechanism (e.g. Tomasello, 1999, 2000; Whiten, 2000). However, if we weigh the pros and cons of combining these research fields, we are still convinced that the benefits are much greater than the disadvantages.

Given that apes apparently can be enculturated, at least to some degree, one might ask to what degree this might also apply to robots. Obviously, the experimental work on Cog and Infanoid is still in its beginning stages, i.e. they simply have not yet gone through any prolonged epigenetic development. Nevertheless, one might want to address already now the question exactly what could be expected to be the outcome of such a process. Will social situatedness and interaction with human caregivers lead to internalisation in Vygotsky's sense? And, consequently will it lead to the "emergence of intentionality, consciousness and meaning" in humanoid robots, as Zlatev (2001) envisioned? We have argued in detail elsewhere (Sharkey & Ziemke, 2001; Ziemke, 2001, 2002) that this would not be the case. It should be noted that this would not imply any 'failure' of humanoid robotics. It might very well turn out to be extremely useful from a 'weak AI' or cognitive modeling perspective, or from an engineering or human-machine interaction perspective, but we doubt that it could lead to the development of phenomenal robot minds or intrinsic meaning in Searle's above 'strong' sense.

That means, we believe, that even if robots like Cog or Infanoid or their successors did develop human-like behavior, it would still only be human observers interpreting this behavior as 'meaningful'. One of the reasons is that the behaviors currently exhibited by Cog and Infanoid, and the mechanisms underlying them, have not emerged ontogenetically as in humans or other primates, but rather they have been 'built in' into the robots. For example, the implemented ability to point to a visual target in *Cog*, is just a 'built in' behaviour, since it just derived from a computational mapping between hand and eye co-ordination, and is not actually a result of shared attention as in human beings. Instead, the robot actually simply points towards the object at the center of its visual field, without actually sharing attention towards a target of mutual interest with a human collaborator. Furthermore, *Cog's* pointing to a visual target has not been bootstrapped through human interaction as a social learning mechanism. Instead, it has been "learned over many repeated trials without human supervision, using gradient descent methods to train forward and inverse mappings between a visual parameter space and an arm position parameter space" (Brooks *et al.*, 1998, p. 75-76). Similarly, *Infanoid* can seemingly accomplish joint attention to some extent with a person, focusing on an object of shared interest, but actually the creators have been forced to 'build in' some tricks in order to implement this behaviour. In this case, there is a 'colour preference' for 'red' so that the robot can distinguish and locate the object of shared interest, a red or pink toy (Kozima, personal communication). No doubt, it is certainly not impossible to implement such behaviours without any 'tricks', but would that make the behavior intrinsically meaningful to the robot itself?

In terms of Vygotsky's theory, we would like to argue that Cog and Infanoid might be exposed to the right sociohistorical factors, but they simply lack the necessary biological factors. Admittedly, we do not know exactly which those are. In Zlatev's (2001) terms, the question is, what exactly is the required "naturalistic embodiment"? It might be worth noting that Zlatev himself did not make any strong claims concerning whether or not Cog or Infanoid actually were sufficiently 'naturalistic'. We have elsewhere (e.g., Sharkey & Ziemke, 2001; Ziemke, 2001; Ziemke & Sharkey, 2001) argued that the 'ingredient' missing in today's robots might be the autopoietic, i.e. self-creating and -maintaining, organisation of living systems (Maturana & Varela, 1980), and Zlatev (personal communication) does agree to this. In sum, we agree with Vygotsky (cf. above) saying that "culture creates nothing; it only alters natural data in conformity with human goals". That means, somewhat simplified, social situatedness and interaction with human caregivers will not suffice to facilitate the development of intelligence and intentionality in robots, if they are not made from the right 'material'.

Putting aside the question whether or not current approaches to humanoid robotics will lead to phenomenal robot minds, we would like to point out that the issue more relevant in practice might be the other side of the social-situatedness-coin anyway. Regardless of whether or not a humanoid robot could be socially situated in the human world and intelligent in a strong sense itself, it is simply a fact that this type of technology allows humans to be or become more socially situated in the world of artefacts. That means the real strength of humanoid robotics, or developing artefacts in general, might not be its role as a 'strong' robotic AI, but rather its potential to facilitate more 'natural' human-machine interaction, allowing humans to interact with artefacts in the way they are used to interact with each other.

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References

Billard, A. and Dautenhahn, K. (1997) *The social aspect of communication: A case study in the use and usefulness of communication for embodied agents.* Poster presentation at the European Conference on Artificial Life 97.

Billard, A. and Dautenhahn, K. (1998) Grounding communication in autonomous robots: An experimental study. *Robotics and Autonomous Systems,* 24, 71-79.

Billard, A. and Dautenhahn, K. (1999) Experiments in learning by imitation - grounding and use of communication in robotic agents. *Adaptive Behavior, 7* (3), 411-434.

Billard, A., Dautenhahn, K. and Hayes, G. (1998) Experiments on human-robot communication with Robota, an imitative learning and communication doll robot. In *Proceedings of the 1998 SAB Workshop on Socially Situated Intelligence.* Zurich: Switzerland, Technical Report CPM-98-38, Centre for Policy Modelling, Manchester Metropolitan University.

Breazeal, C. and Scassellati, B. (2000). Infant-like social interactions between a robot and a human caretaker. *Adaptive Behavior*, (8)1, 49-73.

Brooks, R. A. (1991) Intelligence without representation. In *Proceedings of the Twelfth International Joint Conference on Artificial Intelligence* (pp. 569-595). San Mateo, CA: Morgan Kauffman.

Brooks, R. A. and Stein, L. A. (1994) *Building brains for bodies*. Autonomous Robots, 1(1), 7-25.

Brooks, R., Breazeal, C., Marjanovic, M., Scassellati, B.and Williamson, M. (1998) The Cog project: Building a humanoid robot. In C. Nehaniv (Ed.), *Computation for metaphors, analogy, and agents* (pp. 52-87). New York: Springer.

Clancey, W. J. (1997) *Situated cognition: On human knowledge and computer representations.* New York: Cambridge University Press.

Clark, A. (1997) *Being there – putting brain, body and world together again.* Cambridge, MA: MIT Press.

Dautenhahn, K. (1995) Getting to know each other – Artificial social intelligence for autonomous robots. *Robotics and Autonomous Systems*, 16, 333-356.

Dautenhahn, K., Ogden, B. and Quick, T. (in press) From Embodied to Socially Embedded Agents – Implications for Interaction-Aware Robots. *Cognitive Systems Research*, to appear in 2002.

Davydov, V. V. and Radzikhovskii, L. A. (1985) Vygotsky's theory and the activity-oriented approach to psychology. In J. V. Wertsch (Ed.) *Culture, communication and cognition* (pp. 35-65). New York: Cambridge University Press.

Edmonds, B. (1998) Capturing social embeddedness: A constructivist approach. *Adaptive Behavior*, 7(3/4), 323-347.

Hallam, J. C. and Malcolm, C. A. (1994) Behaviour: Perception, action and intelligence – The view from situated robotics. *Proc. Royal Society Land A, 349*, 29-42.

Harnad, S. (1989) Minds, Machines and Searle. Journal of Theoretical and Experimental Artificial Intelligence, 1, 5-25.

Harnad, S. (1990) The symbol grounding problem. *Physica D, 42*, 335-346.

Hendriks-Jansen, H. (1996) *Catching ourselves in the act – situated activity, interactive emergence, evolution, and human thought*. Cambridge, MA: MIT Press.

Husbands, P., Harvey, I. and Cliff, D. (1993) An evolutionary approach to situated AI. In A. Sloman, D. Hogg, G. Humphreys, A. Ramsey and D. Partridge (Eds.), *Prospects for Artificial Intelligence*, (pp. 61-70). Amsterdam: IOS Press.

Hutchins, E. (1995) *Cognition in the wild.* Cambridge, MA: MIT Press.

Kirshner, D. and Whitson, J. A. (1997) Editors' introduction to situated cognition: Social, semiotic, and psychological perspectives. In D. Kirshner and J. A. Whitson (Eds.) *Situated Cognition: Social, semiotic, and psychological perspectives*, (pp. 1-16). Mahwah, NJ: Lawrence Erlbaum Associates.

Kozima, H. (2000) Infanoid: An experimental tool for developmental psycho-robotics. *International Workshop on Developmental Study,* Tokyo.

Kozima, H. and Yano, H. (2001) A Robotogenetic Model of Human Social Development. *International Workshop on the Relationship between Cognitive and Linguistic Development*, Thailand.

Kozulin, A. (1986) Vygotsky in Context. In: Lev. S. Vygotsky, *Language and thought*, (pp. *xi-lvi*). Cambridge, MA: MIT Press.

Lakoff, G. and Johnson, M. (1980). *Metaphors we live by*. Chicago: University of Chicago Press.

Lakoff, G. and Johnson, M. (1999) *Philosophy in the flesh: The embodied mind and its challenges to western thought.* New York: Basic Books.

Lave, J. (1991) Situated learning in communities of practice. In L. B. Resnick, J. M. Levine and S. D. Teasley (Eds.), *Perspectives on socially shared cognition.* American Psychology Association, Washington, DC.

Maturana, H. R. and Varela, F. J. (1980) *Autopoiesis and cognition: The realization of the living.* Dordrecht: Reidel.

Pfeifer, R. and Scheier, C. (1999) *Understanding intelligence.* Cambridge, MA: MIT Press.

Povinelli, D. J., Bering, J. M. and Giambore, S. (2000) Toward a science of other minds: Escaping the argument by analogy. *Cognitive Science, 24 (3),* 509-541.

Risku, H. (in press) Situatedness in Translation Studies. *Cognitive Systems Research,* to appear in 2002.

Savage-Rumbaugh, S., Shanker, S. G. and Taylor, T. J. (1998). *Apes, language, and the human mind.* New York: Oxford University Press.

Searle, J. (1980) Minds, brains and programs. *Behavioral and Brain Sciences, 3,* 417-457.

Scassellati, B. (1998) Imitation and mechanisms of joint attention: A developmental structure for building social skills on a humanoid robot. In A. Nehaniv (Ed.), *Computation for metaphors, analogy and agents, Vol. 1562 Springer Lecture Notes in Artificial Intelligence.* Berlin: Springer-Verlag.

Scassellati, B. (2000) How robotics and developmental psychology complement each other. *NSF/DARPA Workshop on Development and Learning,* Michigan State University, Lansing, MI.

Sharkey, N. E. and Ziemke, T. (2001) Mechanistic versus phenomenal embodiment: Can robot embodiment lead to strong AI? *Cognitive Systems Research 2(4),* 251-262.

Sinha, C. (2001) The epigenesis of symbolization. In *First International Workshop of Epigenetic Robotics: Modeling Cognitive Development in Robotic Systems.* Lund University Cognitive Studies vol. 85 Lund, 85-94.

Suchman, L. A. (1987) *Plans and Situated Actions: The Problem of Human-Machine Communication*. New York: Cambridge University Press.

Taylor Parker, S. and McKinney, M. L. (1999). *Origins of Intelligence.* Baltimore: The Johns Hopkins University Press.

Tomasello, M. (1999) *The cultural origin of human cognition.* Cambridge, MA: Harvard University Press.

Tomasello, M. (2000) Primate cognition: Introduction to the issue. *Cognitive Science, 24 (3),* 351-361.

Varela, F. J., Thompson, E. and Rosch, E. (1991) *The embodied mind: Cognitive science and human experience.* Cambridge, MA: MIT Press

Vygotsky, L S. (1962) *Thought and language.* Cambridge, MA: MIT Press. (Original work published in 1934).

Vygotsky, L. S. (1978) *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press. (Original work published in 1934).

Wertsch, J. V. (1985) *Vygotsky and the social formation of mind.* Cambridge, MA: Harvard University Press.

Whiten, A. (2000) Primate culture and social learning. *Cognitive Science, 24(3),* 477-508.

Ziemke (2001). The Construction of 'Reality' in the Robot: Constructivist Perspectives on Situated AI and Adaptive Robotics. *Foundations of Science*, 6(1), 163-233.

Ziemke, T. (2002). On the epigenesis of meaning in robots and organisms. *Sign Systems Studies*, 30(1), 101-111.

Ziemke, T. and Sharkey, N. E. (2001) A stroll through the worlds of robots and animals: Applying Jakob von Uexküll's theory of meaning to adaptive robots and artificial life. *Semiotica,* 134 (1/4), 701-746.

Zlatev, J. (2001) The epigenesis of meaning in human beings, and possibly in robots. *Minds and Machines, 11*, 155-195.