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3 “Being There” in a Virtual World: an Enactive Perspective on Presence and its Implications for Neuropsychological Assessment and Rehabilitation

Abstract: The most recent advances in neuroscience have shown that there is an increasing necessity of resuming the embodied vision of cognition and how it could produce a significant impact on research in neuropsychology. Moreover, from the enactive cognition perspective the ability of humans to acquire knowledge from environment can be conceived as the product of continuous cycles of embodied perception and action in which the mind and the world are constantly and mutually involved. This reciprocal relationship is fairly easy to understand when an agent is interacting within a not simulated complex space. It is rather more difficult to understand if the agent has a neurological disease that affects the ability to manage her everyday environment. The introduction of Human Computer Confluence (HCC) approach and its possible digital scenarios (such as virtual environments) has proposed new challenges for enactive cognition research because it provides atypical patterns of interaction that, through the emergence of a sense of presence, influences cognitive representations and meaningful experiences. In this chapter the agents’ sense of presence in a virtual environment and its implications for the ability to catch appropriate affordances for action in space will be discussed. With the aim to clarify the similarities and differences between natural and HCC environments, the chapter starts from the explanation of the enactive cognition approach and will present a recent research approach on this topic in neuropsychology. At last the implications for the assessment and rehabilitation of high level cognitive functions in elderly population and neurological patients will be provided.

Keywords: Embodiment, Enactive Cognition, Neuropsychology, Virtual Environments, Presence

3.1 Introduction

In the last century the human processes involved in interacting with technology was mainly characterized from the Model Human Processor described by Card, Moran and Newell in 1983. This model includes the perceptual, the motor and the cognitive systems as the modules through which Human Computer Interaction (HCI) makes possible (Card, Moran, Newell, 1983). The HCI has influenced the majority of the technological applications that are still widely in use and it also has extensively influenced the classical paradigms of cognitive science.

At present, with the upcoming pervasive and ubiquitous computing era, technologies become embedded, operating with its complete physical environment as interface and supporting a more implicit interaction that involves all human senses. The explosive growth of web-based communications and, at the same time, the radical miniaturization of technologies have reversed the principles of human computer interaction. Instead of text-based commands and generic interaction devices (such as keyboards and joypads), in fact, human body actions directly features a intuitive way to interact with objects in a technology-based environment. Up until now considered as the interaction concerns when humans approach technology, more recent observations see humans and technology apparently approach each other confluently. Thus, by “manipulating” technologies, by simultaneously involving different human senses, and by considering interaction related to the physical and psychological situation in which it occurs, the traditional understanding of having an interface among humans and computers expires. Accordingly, Human Computer Confluence (HCC) that proposes human and computer activity at a confluence appears to be a more adequate definition (Ferscha, Resmerita, Holzmann, 2007).

The first definition of HCC refers to an implicit or even embedded interaction between humans and technology system components that provides the means to interact with the surrounding environment in a transparent natural and pervasive way. Among some of the main features proposed by the HCC paradigm there is the idea of technologies self-organization and interoperation. It underlines the possibility of detecting and interpreting the overall environmental situation and consequently differentially adapt the support they provide to specific user needs during her interaction with those technologies (e.g. by including the interface auto-calibration or the coordination among different technological tools). Accordingly, new classes of devices evolve and become able to adapt their physical properties to users' current situational context. Examples might include body worn displays, smart apparel, interactive large display walls, and architecture annotated with digital information. More recent advances have also introduced innovative technology able to directly connect itself with the human sensory and neural system in terms of in-body experiential interactions.

Moreover the ability to capture and correlate human experiences by technology, as well as the ability of technology to provide meaningful experiences to end-users could be considered one of the main challenge of HCC. Through innovative communication systems and ubiquitous networked sensors – able to taking into account body movements, facial expressions, event-related physiological and brain activity – in fact, it could be feasible to introduce a radically new styles of human-to-technology communication. Moreover with the introduction of a technology-based representations of human engagements and experiences, derived from the combination of multimodal perceptual stimuli with the human cognitive model, a new challenge of experiences and emotions attunement and sharing between man and machine seems to be possible.

Thus, HCC paradigm seems to provide a more intuitive meaning of interaction and appears to have several contact points with the so-called enactive cognition perspective that is closely based on a peculiar definition of interaction named embodied interaction. As Francisco Varela, Evan Thompson and Eleanor Rosch stated, in fact, enactivism relies on a fundamental concept: cognition and environment are inseparable, and organisms bodily enact with each other from which they acquire knowledge (Varela, Thompson, Rosch, 1991). Accordingly, the interaction with a context is a continuous developing process not simply guided by agent goals or motor actions; rather it is agent’s ways of experiencing the context in which she is included that involves sensorimotor processes and perpetually “welds” together perceptions and actions. Moreover, one of the ground concept of enactivism is co-emergence. It focuses on the idea that the change of both an agent and its environment depends on the interaction between this agent and the specific environment. When agent and environment interact, they are structurally coupled and they co-emerge.

In this paper I will explore the enactive cognition approach and its link with the sense of presence possible within virtual environments, I would like to clarify how, with respect to the traditional interaction concept provided by HCI – that considers the interface as the main link among humans and computers – it is rather the confluence concept among embodied activity and an experiential technology-based environments presented by HCC that best defines the relation among humans and computers. The second part of this contribution aims in determine how this theoretical bridge could be suitable for applied neuroscience.

3.2 Enactive Cognition

In the last decade, following the input derived from mirror neuron discovery – that suggests the strong linkage between perception and action – the classical approach to the study of cognition would have to be replaced by an enactive one. This approach considers living beings as autonomous agents that actively generate and maintain their own coherent and meaningful patterns of activity. Within this situated view of the mind, cognition is not the result of aggregation and organisation of noteworthy information from the outside world; rather it is the product of perception-action cycles where mind and world are constantly at play. This shift also reshaped the concept of interaction: the dynamic building up of meaning through the cognitive and affectively charged experience of self and not-self (e.g. the environment, an object or other agents).

A good description of this perspective may be found in studies on embodied cognition (Varela, Thompson, Rosch, 1991). Within the embodied cognition, the body becomes an interface between the mind and the world, not so much as a collector of stimuli, rather providing it as a stage for the enactment of a drama, an interface allowing a merger between thought and the specific surrounding space. The sensorimotor

coupling between the organisms and the environment in which they are living determines recurrent patterns of perception and action that allow experience and knowledge acquisition. Thus, enactive knowledge unfolds through action and it is stored in the form of motor responses and acquired by the act of doing. The human mind is embodied in our organism and it is not reducible to structures inside the head, but it is embedded in the world we are enactively interacting with (Thompson, Varela, 2001).

According to this perspective it is reasonable to accept the suggestion, originally advanced from ecological psychology (Gibson, 1977), that an individual perceives the world not in terms of objective and abstract features, but directly in terms of spaces of possible actions: “affordances”. An affordance is a relational notion. The possibilities for action depend on the encounter of the characteristics of the two poles of the interaction, and are shaped by the overarching activity in which the agent is involved. Therefore, in exploring a an environment an individual will take embodied opportunities for action (affordances) that are granted to the agent. Such affordances are not an intrinsic property of the environment alone, but a property of the interaction between the agent and the environment. The availability of the affordances depends on the activities in which the agent is participating at each moment.

Within this perspective cognition becomes a complex co-evolving interactional process of systems mutually affecting each other and influencing the environment they are immersed in. Consequently cognition can't be described as in some sense a passive information elaboration process, rather it is an active biological, social and situated phenomena. In one definition it is enactive. Every living system engages in cognition by a action-feedback-reward system through which she learns from and adapts to her environment. At the same time, this system also co-emerges with the world it lives in because her activity is a domain of possibilities (affordances) and emerges from a sequence of “structured coupling” where every change causes responses in the dynamics of an ever-evolving world (Varela, Thompson, Rosch, 1991). Thus, environment doesn't direct agent's decision but unfolds in events that evoke these particular possibilities of action. By this way agent is believed to be an integral part of the environment itself.

Knowledge acquisition therefore, is embedded in action and it is not about creating abstract representation of the context; rather it is an ongoing exploration of possibilities (that includes the self and the environment) during interaction in order to adapt to the evolving situation. Consequently, a meaningful experience is not basically a collection of selected events but it constitutes every intuition, emotional fluctuation, imaginative aspect that emerges from any visible and invisible action, even those that are at the backdrop of our attention. This approach has been some specific implications for neuroscience research.

3.3 Enactive Neuroscience

Embodied cognition has been recently described as a spectre who is haunting the research laboratories ((Goldman, De Vignemont, 2009)). From the neuroscientific perspective, after the mirror neuron discovery, the term embodied generally means that body structure and bodily actions play a crucial role in cognition. This vision emphasizes the central role of representations mapped on body for knowledge acquisition. Representations in these terms are characterized as a distinctive class of mental states by virtue of their specific format rather than their general content. Mental states are embodied because of their peculiar bodily format and might have partly overlapping contents with other states while differing from one another in their format. Thus, the body of a cognitive representation binds what a cognitive representation can stand for (Gallese, Sinigaglia, 2011). For instance, an agent who intends to use an object has to plan and execute a motor act according to her own body characteristics (such as height, posture and physical strength). It is this embodied format that constrains the representation not only of a single motor goal, but also of a sequence of behaviours in a complex space. This defines an act as every time different from a pure a-priori propositional representation of a generic motor act. From these statements connections with the concept of affordance and the enactive approach to cognition appear to be getting more clearly defined.

In spatial orientation, for example, by using affordances during an environment exploration an agent is capable of creating relationships between landmarks and, at the same time, of entertaining high-level spatial maps. Obtaining a high level spatial map allows an agent to draw spatial inferences while she is engaged in an embodied egocentric exploration. Recent fMRI studies support this enactive perspective of spatial cognition, showing how specific brain regions (e.g. the retrosplenial cortex) have a key role in translating the high level spatial information in egocentric spatial input during wayfinding. This suggests that the acquisition of knowledge is inseparable from the egocentric/embodied perspective and from action (Byrne, Becker, Burgess, 2007).

Despite neuroscience evidence of enactive cognition, neuropsychological assessment has been largely utilising tests that provide subjects with stimuli mainly based only on the not embodied cognition approach (Lezak, 2004). Generally in fact, the Mini Mental Evaluation Exam (Folstein et al., 1975) is used for general cognitive level evaluation, the Corsi's Block-tapping test (Kessels et al., 2000) is utilised to assess spatial memory, the Tower of London task (Shallice, 1982) is used for planning ability evaluation. All the above tests indubitably constitute an important vehicle through which the different aspects of cognition can be evaluated, but they do not allow the assessment of the active and body-centred interaction with the environment from which an agent acquires knowledge. This aspect results in an important bias for the neuropsychological evaluation because it requires subjects to use abstract simulations of tasks and to infer how the test stimuli could be like from a situated perspective.

In the last decades one of the main vision of HCC is to consider technology as a cognitive extension, able to develop new forms of knowledge and amplify humans' cognitive abilities. Technology-based environments, in fact, integrate so closely with agents that they will become a part of their extended minds in building internal models of the world and providing control functions. Accordingly, a large amount of literature supports the evidence that knowledge obtainable from 3D computer simulated environments (such as virtual environments) is largely comparable to the one obtainable from the active interaction with not simulated environments. It is due to the sense of presence experienced in virtual reality simulations. Presence is commonly defined as the subjective feeling of "being there" (Riva, Davide, Ijsselstein, 2003). It's largely agreed that during the exploration of a virtual environment agents create cognitive representation of it and obtain from it a meaningful experience. According to those evidences, in fact, virtual environments have been introduced in neuroscience and experimental psychology for the study of cognition (Morganti, 2003; 2004).

I would like to underline here that a full understanding of the great opportunity provided from virtual environments for neuroscience requires a multidisciplinary perspective that involves not only neurological research but also cognitive psychology and information communication technology. The great challenge, in fact, is to clarify what could be the role of emerging technologies in such process and how can it support us in delineating innovative and plausible scenarios for the future clinical work. In doing that the HCC perspective could help us defining long-term clinical goals and in understanding how the new technology is going to support neurological population on cognitive and social level, and in how it will change patients' perception and models of reality.

While agreeing with the HCC vision, there is the necessity to deepen some aspects about the experiential differences derived from the interaction with a simulated and a not simulated environment. By adopting an embodied approach to sensing people's state, in fact, virtual reality systems provide not just passive motion sensors but introduce also new challenges in implementing real-time and dynamic action possibilities. This mechanisms is able to create innovative fully interactive applications that enactively adapt themselves according with users activities, providing users with a sense of action ownership that results in a presence feeling within the simulated environment. Before to largely use it in neuro-cognitive research, it become necessary to determine how this "being there" experience could influence cognition and can evidence differences between healthy subjects and neurological patients.

3.4 Enactive Presence in Virtual Reality

Several authors considered the *sense of presence* as mainly deriving from the result of subjective involvement in a highly interactive virtual environment (Slater, Wilbur, 1997). Presence, in fact, would be strong inasmuch as the virtual system enables an

inclusive, extensive, surrounding and vivid illusion. The immersive quality of virtual reality would be enhanced by the perceptive features and the proprioceptive feedback provided by the technology. Accordingly in the last years research on presence has emphasized the role that activity plays in directing attention within complex interactive situations. The specific role of interaction with technology in creating presence was firstly considered by Lombard and Ditton (1997), who defined presence as the “perceptual illusion of non-mediation”. In this perspective, presence occurs when a person misperceives an experience mediated by technology as if it were a direct (that is, non-mediated) one. Presence, thus, would not be a property of technology, rather it could vary depending on how much the user acknowledges the role of technology and could therefore be yielded by different kind of technologies. Thus, not only highly immersive technological solutions are needed to experience presence but also subjective involvement plays an important role. Sanchez-Vivez and Slater (2005) claim that visual realism does not strongly contribute to presence and that of particular importance is the degree to which simulated sensory data matches proprioception during a virtual environment exploration. Experiencing presence does not merely depend on appearances but is rather a function of the interaction between the subject and the environment. It suggests that it is the role of the subject’s own body in eliciting presence. The sense of agency ownership could be provided not only by the visual reference of the agent body in the virtual environment, rather, what counts is the dynamic of the interactions between the body and the world that a virtual reality is able to support through a continuous coupling between perception and action.

Concordant with this theoretical position the definition of presence can be integrated within the enactive perspective described in the previous paragraphs and can be addressed to the various combination of physical and digital spaces today available. At present, for example, it is possible to augment a physical space with video observed through a mobile screen or interact with a digital space through some physical device or wearable movement sensors. Thus, the physical and the digital become woven together into hybrid spaces with their own properties. In cognitive science the term to define this kind of mixed space is ‘blended’ and it refers to a cross domain mappings and conceptual integration to thought process that are grounded in physically-based spatial schemas. A blend is defined as a cognitive structure that emerges when putting together two or more input spaces – mental spaces derived from different domains of knowledge (Fauconnier, Turner, 2003). They are defined as temporary cognitive models engaged in thinking, talking and planning subsequent actions. There are minimum four mental spaces involved in a blending process: the two input spaces (for example the physical and digital), one generic space containing the elements that are shared by the two input spaces and, finally, the blend – the emerging mental space possessing meanings extracted from the generic space but also new, emergent qualities that neither the input spaces nor the generic space possessed before entering the blending process. The blended space will be more

effective if the physical and digital spaces have some recognizable and understandable correspondences.

The concept of blended spaces supports us in understanding how virtual reality experiences could be interpreted as the next level of enactive cognition. People will move through these spaces, following trajectories that weave in and out of physical and digital space, and will feel present within it. To be in this kind of space, in fact, depends on a suitable integration of aspects relevant to an agent's movement and perception, to her actions, and to her conception of the overall situation in which she finds herself, as well as on how these aspects mesh with the possibilities for action afforded in the interaction with the virtual environment (Carassa, Morganti, Tirassa, 2004; 2005). According to this vision, during the interaction with a digital environment an agent will choose and perform specific actions whose goals are part of a broader situation, which she represents as the weave of activities that she participates moment by moment. These activities are, in their turn, supported by goals, opportunities for action, and previous knowledge, that give them meaningful experiences. Therefore, in exploring a virtual environment an individual will take embodied opportunities for action that are granted to the agent, and such affordances are not an intrinsic property of the environment alone, but a property of the interaction between the agent and the environment. The availability of the affordances depend on the activities in which the agent is participating at each moment. In supporting the representation of herself as an agent, who carries on a narrative about herself in the world, the environment (even a virtual one) has always a subjective rather than objective nature. Finally, the degree to which people will feel really present in this kind of space is a measure of the quality of the user experience, of the naturalness of the medium interaction and of the appropriateness of digital content to the characteristics of the physical space.

Following the enactive interpretation of presence I am proposing that the differences between the action (as in the real world) and the simulation of an action (as in virtual reality) reflects a distinction between ability to anticipate the results of changing one's frame of reference with respect to the environment and the ability to imagine the results of changing the position of an object in the environment while maintaining one's current orientation in the physical environment. Specifically interaction ability with a virtual environment depends on the "cognitive anticipation" of agent behaviour in a particular place with a specific frame of reference. Consequently, embodied interaction ability creates an expectation/simulation of movement that in virtual reality was more manageable with a high level of presence.

At present the main open question is on how experiential differences derived from the interaction with a simulated and not simulated environment could influence cognitive representations. Moreover, as defined before, according with the technology they are using people will be differently present in the blended space, moving between and within them and moving up and down the layers of experience. The next paragraph aims in underline which are the critical difference between these two

conditions and how the sense of presence can efficaciously support interaction and knowledge acquisition. I propose this point constitutes, in fact, the key factor for the use of virtual reality in neuropsychology not only for assessment, but also for the rehabilitation of cognitively impaired people.

3.5 Enactive Technologies in Neuropsychology

Although it has therefore been discussed about the importance of the enactive cognition approach and about its implication for the sense of presence for knowledge acquisition in digital spaces, how to use HCC technological solutions to assess specific cognitive functions it remains still widely unexplored. A key requirement for all HCC applications, in fact, is to recognize complex human activities in real-world environments over long time periods and in unconstrained environments and to provide users with a congruent support in choosing new opportunity for action in everyday life. This approach implies a number of consequences which are problematic when dealing with complex activities over different time periods in blended environments. In this case HCC technology must enactively adapt to new, likely unforeseen, situations encountered at run-time, by continuously tracking changes in the way user's activities map to sensor signals, and by being able to adapt itself to the way a user executes activities.

For how concerns one of the main challenge everyday space provide us, such as spatial orientation, for example, the reciprocal relationship between perception and action that underlies this ability is quite easy to understand when an agent is placed in a natural place, such as her house or a city square. However, this link is more difficult to understand when the agent is provided with a simulated space, such as a map that provides the agent with an allocentric perspective, or when she is placed in a virtual environment that provides the agent with an egocentric perspective. In the last decade, together with paper and pencil spatial grids and sketched maps, virtual reality environments were widely used in cognitive neuropsychology to study spatial orientation (Morganti, 2004). At present the great challenge in spatial cognition assessment is to determine if the orientation obtainable from a digital interactive environment might differ from the spatial orientation obtainable from a simulation of the same environment based on an analogical simulation (e.g. a sketched map). In the first type of simulation, in fact, an agent has an egocentric perspective on the environment and she can move within it, while in the second type of simulation, an agent has an allocentric perspective on the environment that requires a mental imagery effort to be translated in action. I claim that both perspectives are essential for spatial orientation in a complex environment and the linkage between them needs to be further investigated in order to obtain an effective HCC solution to support agents in exploring the surrounded everyday space. It could be essential not just to improve the use of complex spaces in daily activities, but it could be even more crucial for supporting

the daily activities in people who have suffered neurological damage and which are no longer able to manage the surrounding spaces.

At this regard, for example, in the last years a virtual version of the Money's Road Map test was developed (VR-RMT; Morganti et al., 2009). Whereas the classical version of the test requires a mental imagery right/left turning to explore a stylized city provided to the subject in an allocentric perspective, the VR-MRT is a 3D version of the same environment in which participants can navigate by actively choosing right/left directions in an egocentric perspective. The introduction of this virtual version of the test provides the opportunity to observe several implications according to the enactive approach to cognition. From an enactive perspective, in fact, there is a difference in imagining a turn, as in classical version of the test, and actively performing a turn in order to obtain a spatial perspective from the virtual world as in the VR-RMT. Accordingly these two different spatial tasks, as they provide different embodied affordances, results in different orientation outcomes. Specifically, it might be argued that, by providing an external representation of the route perspective, these differences are underlined by the type of right/left turns and by their increasing complexity. This example could give us the possibility to understand how a HCC technological solution, such as virtual reality, supports perspective taking and could provide different performances in spatial cognition.

From a work of Gray and Fu (2004), we know that, when a computer-based interface is well designed, it supports the possibility of placing knowledge in-the-world instead of retrieving it from-in-the-head, in order to have it readily available when an agent needs it. Accordingly agents might prefer perfect knowledge in the world to imperfect knowledge in the head. Offloading cognitive work onto the environment (Wilson, 2002) could constitute one of the main advantages of the active interaction supported by a HCC system: it allows guiding orientation by obtaining spatial perspectives from in the world (the different spatial snapshots encountered by the agent after a right/left turn in virtual world) rather than retrieving it from in the head (the different inferences on how a perspective would be after a right/left turn) and could provide agent with new affordance for wayfinding. On this subject Schultz (1991) underlined how to plan in advance a wayfinding in a natural place could be done primarily by imagining egocentric spatial transformations. Thus an agent involved in this task have to imagine how to move on the body axis and finally obtain (and retain) the spatial perspective derived from the turn, whereas in a digital space an agent act the turn on the body axis and finally perceive in the simulated world the spatial perspective derived from that turn. In this case an HCC technology, such as virtual reality, does not require the agents to find their current place each time and the keeping track of each perspective does not require an additional cognitive effort. But, as pointed out by Tversky (2008), our own body is experienced from inside, and the space around our body does not depend on the physical situation per se. In a digital space, such as in the VR-RMT, there could be a dissociation between perspective taking and mental rotation (Hegarty, Waller, 2004). Perspective taking involves imagining the results

of changing one’s egocentric frame of reference with respect to the environment, while mental rotation involves imagining the results of changing the positions of objects and maintaining one’s current orientation in the environment. In accord with Keehner and colleagues (Keehner, Hegarthy, Cohen, Khooshabeh, Montello, 2008), I hypothesize that in the VR-MRT task participants must create a blended space and will be able to use it in order to manage a efficient wayfinding. In doing that they match the perspective that the virtual scenario is providing them to their right/left turn intentions in order to match the obtained perspective with the results of each turn, and this matching has to be tightly coupled with internal cognitive processes. In conclusion the option to offload cognition onto the external visualization provided by this kind of HCC (by observing the perspective resulting from a right/left turn) may require a cognitive effort mainly based on an embodied cognitive process.

3.6 Enactive Knowledge and Human Computer Confluence

As Maturana and Varela stated, stressing embodied action, “all doing is knowing and all knowing is doing” (Maturana, Varela, 1987; p. 27). In this contribution we have discussed on how an agent and the environment, both natural and artificial, are mutually specifying and how cognition is a co-emerging process of enactment of a world and our mind.

In the last paper Francisco Varela wrote before his death Gallagher, Varela, 2001), in order to understand the nature of human experience, several open questions were proposed, such as: How do humans perceive a space? How this perception is different from imagination or memory? Is memory stored in form of linguistic or image codification? Can consciousness exist independently from its context? Are my voluntary movements independent from my body awareness? All these questions were partially answered through investigating the sense of agency as intrinsic and indistinguishable to the action itself. There is, in fact, an intrinsic sense of ownership of the action, essentially based on the anticipation of action goals, that exists prior to the physical execution of the specific action (Georgieff, Jeannerod, 1998; Gallagher, Marcel, 1999). It is this anticipatory mechanism that entangled embodied actions to the context in which they are planned to be executed. Moreover, it is the same functional mechanism that allow to reorganize actions according to contextual changes that might occurs during the execution of actions or to the contextual changes that are yet to happen (Berthoz, 2000). At present, the theoretical questions proposed by Gallagher and Varela appear to be still unresolved if we consider the HCC approach. In a recent paper, Froese and Zimke (2009) argued that technologies can be considered as an opportunity to create hypothetical variations of a particular natural phenomenon by externalizing a crucial part of the imaginative process in what they defined ‘technological supplementation’. I proposed here that the main difference between HCC

experiential environments and non-technology-based contexts lies in the fact that the first extended by technology the cognitive phenomenon we would like to observe.

Specifically in this contribution I want to introduce how enactive technologies could be used in cognitive neuroscience in order to observe the types of representations an agent is able to obtain in order to adaptively interact with a simulated environment within a given activity. For neuropsychological assessment, in fact, a particular type of HCC technological solution, as virtual environments, seems able to maintain the sensorimotor dynamics of embodied agency—that is the locus of selfhood in the not simulated world—and provides us with the possibility to evaluate agent's spatial ability in a situated way. The introduction of such kind of simulation, that supports the sense of being in another place than the physical one, makes it possible to overcome some limitations of current neuropsychological evaluation: the confliction between the need to study cognition in conditions that allow a high methodological control and the need to create situations that have a high ecological validity. Virtual reality, in fact, allows the creation of flexible simulations in which humans can actively perform 'real-life' explorative behaviours in a daily environment. It might be important if the assessment requires a functional localisation of the brain areas involved in a specific kind of interaction while subjects are not allowed to physically move in the environment (such as in fMRI studies). Moreover, rather than lesion localisation the main purpose of the neuropsychological assessment should be to draw conclusions from assessments regarding patients' ability to live independently or return to a previous occupation (Troster, 2000). This issue is extremely important especially in the cognitive assessment of the elderly population, where we can find several "borderline" situations not always detectable with a classical neuropsychological assessment. Specifically it is important to gain a greater understanding of the nature of age-related cognitive impairment mainly because the age-associated limitations could potentially lead to restrictions in daily activities, especially if they are performed in new environments.

Despite this evidence, cognitive decline in healthy elderly population and its role in the difficulties experienced by neurological patients are grossly underestimated. As neurological patients are generally at high risk for cognitive impairments that could have a detrimental impact on everyday performance, they require a specifically contextualized user-centred intervention (Katz, 2005). At present, conventional neuropsychological evaluation and rehabilitation plan still present limited ecological validity and do not fully address the functional implications of cognitive deficits (Burgess et al., 2006). The more valuable solution to this gap could be to introduce new tools for the measurements of cognitive ability "in action", extremely important to individuate a possible rehabilitation plan focussed on patient's instrumental activities of daily living (Hartman-Maeir, Katz, & Baum, 2009). The HCC approach seems to provide us with a great challenge on this issue. There are, however, some considerations that have to be clearly identified in introducing HCC in neuroscience. Several parameters might interfere with HCC-based neuropsychological assessment

(e.g. age-related vision lowering and motor slowing), that may differentiate performance between older and younger adults and may affect interpretation of data findings. It become, for example, strictly necessary to evaluate age differences in experience using computers and playing 3D video games that might influence navigational expertise in a virtual environment (Moffat, 2009). In order to overcome these interfering variables, researchers have either to find new ideas for supporting enactive interaction with technology and specifically provide older subjects with extensive training sections in order to give them the possibility to familiarize with the HCC devices interaction practices.

Several objections about equivalence between natural and digital environment can be moved from the use of such HCC solutions in the cognitive domains. I consider them essentials if we would like to maintain an idea of cognition strictly based on behaviour-representation-feedback model (such as the notion of interaction in HCI approach). From this perspective we need to stress the obvious physical difference between natural and simulated environments in terms of perception, possibility of physical interactions, proprioceptive and vestibular feedbacks, and so on. Contrariwise, I would like to endorse a more enactive view of cognition in which what an agent do during the human computer confluence with technology-based simulations is to maintain her self-identity (through her action ownership) and to treat the context modification she encounters with the anticipation of her action goals (that is not intrinsic to the context itself). From this perspective the artificial-natural reality equivalence problem disappears and the cognitive representation of a context is not determined by the mere perceptual contest but it is based on a co-determination of embodied representation and affordable context in a blended space. It is the co-determination, in the enactive sense, that constitutes sense-making generation in relation to the embodied and intentional perspective of the agent. This disappearing of the boundaries between the affordable situation and agents goals is the enaction of a meaningful world for the agent. Thus, knowledge is acquired in relation to the “being there” sensation an agent experiences both within a natural, a simulated environment or a blended one. It is the presence experience, possible in a human computer confluence, that supports agent’s ongoing identity and the active creation of the overall context meaning possible even in a simulated situation. What makes the world is the significance that is continuously brought forth by the endogenous activity of the agent, as it appears from her affordance perspectives. It is distinct from the pure physical characteristics’, instead depends on the specific mode of co-determination that each agent realizes with its context according to different modes of structural coupling that give rise to different meanings.

At last, HCC paradigm results in an interesting opportunity not only for the more situated clinical neuropsychology evaluation and rehabilitation, but also for providing a test bed for the enactive cognition approach.

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