Introduction to Cognitive Science



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THE EXTENDED MIND





Can a **human + stick** create a temporary **whole new agent-world circuit**, rather than simply exploiting the stick as a helpful prop or tool

What's in an Interface?

"a point of interactive 'contact' between components such that the relevant interactions are well-defined, reliable and relatively simple" (Haugeland 1998, 213).

Haugeland stresses that human sensing typically yields very task-variable, high-bandwidth forms of agent-environment coupling and thus to argue that **no genuine interface** or interfaces separate agent and world.









New Systemic Wholes









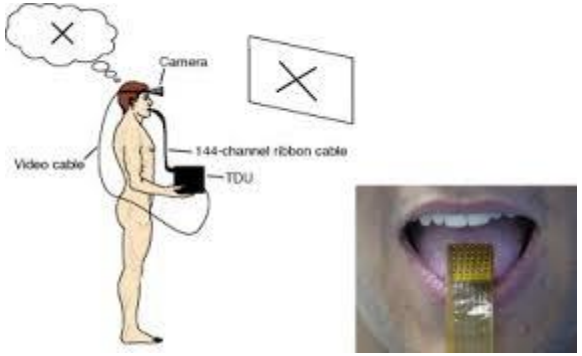
Infants must learn which neural commands bring about which bodily effects, and must then practice until skilled enough to issue those commands without conscious effort.

“it is simply **good design** not to permanently lock in knowledge of any particular configuration but instead to **deploy plastic neural resources** and an ongoing regime of monitoring and recalibration”

Tool to Transparency

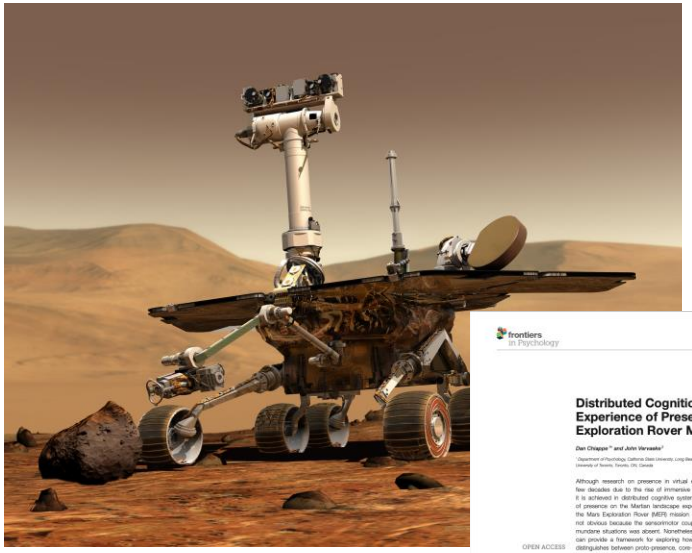
One sign of successful calibration is that **once fluency is achieved**, the specific details of the (old or new) circuitry by which the world is engaged fall **"transparent"** in use.

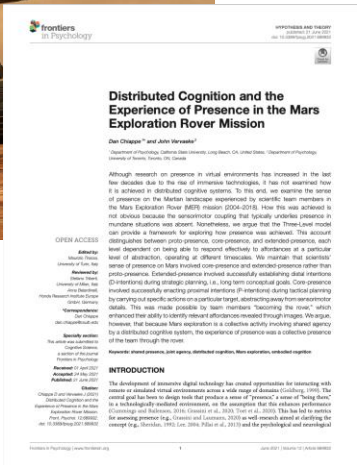




Blind users of **Tactile-Visual Substitution Systems (TVSS)** use tactile signals to "see." They perceive the external world**, not the vest providing feedback**.







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HYPOTHESIS AND THEORY

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Distributed Cognition and the Experience of Presence in the Mars Exploration Rover Mission

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Although research on presence in virtual environments has increased in the last few decades due to the rise of immersive technologies, it has not examined how it is achieved in distributed cognitive systems. To this end, we examine the sense of presence on the Martian landscape experienced by scientific team members in the Mars Exploration Rover (MER) mission (2004–2018). How this was achieved is not obvious because the sensorimotor coupling that typically underlies presence in mundane situations was absent. Nonetheless, we argue that the Three-Level model can provide a framework for exploring how presence was achieved. This account distinguishes between proto-presence, core-presence, and extended-presence, each level dependent on being able to respond effectively to affordances at a particular level of abstraction, operating at different timescales. We maintain that scientists' sense of presence on Mars involved core-presence and extended-presence rather than proto-presence. Extended-presence involved successfully establishing distal intentions (D-intentions) during strategic planning, i.e., long term conceptual goals. Core-presence involved successfully enacting proximal intentions (P-intentions) during tactical planning by carrying out specific actions on a particular target, abstracting away from sensorimotor details. This was made possible by team members "becoming the rover," which enhanced their ability to identify relevant affordances revealed through images. We argue, however, that because Mars exploration is a collective activity involving shared agency by a distributed cognitive system, the experience of presence was a collective presence of the team through the rover.

Keywords: shared-presence, joint agency, distributed cognition, Mars exploration, embodied cognition

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INTRODUCTION

The development of immersive digital technology has created opportunities for interacting with remote or simulated virtual environments across a wide range of domains (Goldberg, 1998). The central goal has been to design tools that produce a sense of "presence," a sense of "being there," in a technologically-mediated environment, on the assumption that this enhances performance (Cummings and Bailenson, 2016; Grassini et al., 2020; Toet et al., 2020). This has led to metrics for assessing presence (e.g., Chamilo and Lommatzsch, 2020) as well research aimed at clarifying the concept (e.g., Sheridan, 1992; Lee, 2004; Pillai et al., 2019) and the psychological and neurological

Incorporation Versus Use

Critic: “You are making quite a song and a dance out of this, what with talk of brand new systemic wholes and so on. But we all know we can use tools and that we can learn to use them fluently and transparently. **Why talk here of new systemic wholes**, of extended bodies and reconfigured users, rather than just the same old user in command of a new tool?”

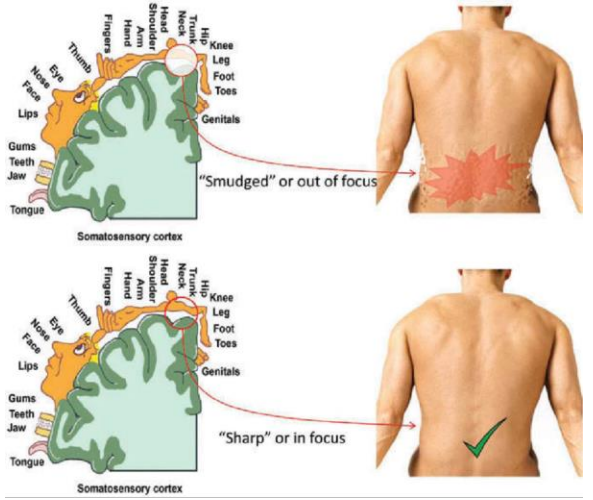
This is the right question…



When we become skilled at using a tool like a stick, it becomes part of our **body schema**, our internal representation of the body's boundaries and capabilities.

"Fluently using a stick, we feel as if we are **touching the world** at the end of the stick, **not... as if we are touching the stick with our hand**."





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Tools for the body (schema)

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What happens in our brain when we use a tool to reach for a distant object? Recent neurophysiological, psychological and neuropsychological research suggests that this extended motor capability is followed by changes in specific neural networks that hold an updated map of body shape and posture (the putative 'Body Schema' of classical neurology). These changes are compatible with the notion of the inclusion of tools in the 'Body Schema', as if our own effector (e.g. the hand) were elongated to the tip of the tool. In this review we present empirical support for this intriguing idea from both single-neuron recordings in the monkey brain and behavioural performance of normal and brain-damaged humans. These relatively simple neural and behavioural aspects of tool-use shed light on more complex evolutionary and cognitive aspects of body representation and multisensory space coding for action.

To act efficiently in space, our brain must not only localize any objects of interest in extrapersonal space but also hold a constantly updated status of the body shape and posture. The 'Body Schema' of classical neurology [1,2] originally indicated this status as an ongoing, mainly unconscious integration of successive proprioceptive signals [1], sometimes in contrast to a more conscious knowledge about the body – the 'Body Image' [3]. The somewhat anecdotal concept of body schema has been greatly enriched by modern neuroscience [4,5].

First it has been found that besides proprioception, other sensory modalities (typically somatosensory and visual) are crucial to its construction [5–12]. Second, single-neuron recordings in the monkey brain have changed the vision of a 'purely perceptual' construction of a body map in the brain towards a more multicomponential, action-oriented one. In this view, multiple fronto-parietal networks integrate information from discrete regions of the body surface and external space in a way which is functionally relevant to specific actions performed by different body parts (e.g. [13–17]).

Of particular interest to this review is the discovery of premotor, parietal and putaminal neurons that respond both to somatosensory information from a given body region (i.e. the somatosensory Receptive Field; sRF), and to visual information from the space (visual Receptive Field; vRF) adjacent to it [18–20]. Importantly, for some such bimodal neurons, the vRF remains anchored to the body part when this is moved in space [16,18]. This system may be crucial for coding action space in coordinates centred on the body [13,15,16,21]. In this review we will refer to the widely [4,5,22–25] but perhaps ambiguously [26] used term Body Schema, or to 'body representation' to indicate such a neural system whereby space coding for action is centred on constantly updated, multisensory information about the body.

Tool-use: a clue to the plasticity of body representation and space coding

Although the length of our effectors (mainly the arms) limits our action space, we can use many different tools (from forks to pick up hot food to hyper-technological telesurgery devices) to extend our physical body structure and, consequently, our action space.

Early intuitions (e.g. [1]) suggested that manipulated objects, or items of clothing [27,28] become 'incorporated into the body schema'. In recent years there has been an explosion of interest in trying to verify such an intriguing hypothesis.

The simple model used in many experiments discussed in the present review is to observe changes in the behaviour and/or the neural activity of monkeys and humans following the use of simple tools (for example a rake) to extend reaching space. Such data are important both for gaining further knowledge about the plasticity of body representations in the brain, and to develop new technological tools. Furthermore they allow speculation about the possibilities of 'intelligent' use of simple and complex tools in monkeys.

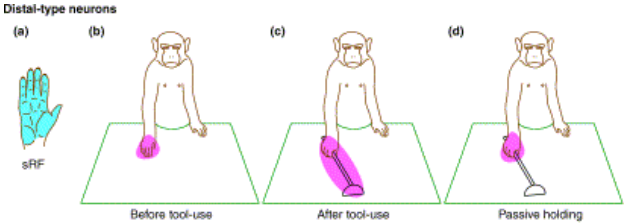
Neurophysiology of tool-use in macaque monkeys

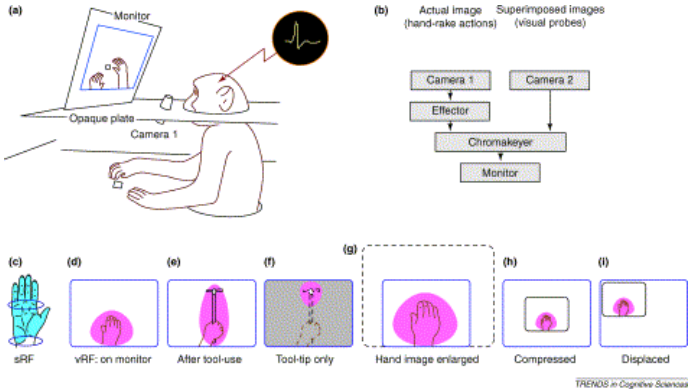
Japanese macaques can be trained to be dexterous tool-users [29], even though they rarely exhibit tool-use behaviour in their natural habitat (see Box 1). After two weeks of training [30], when a food pellet was dispensed beyond the reach of the hands, monkeys skilfully used a rake to pull the food closer, where they could reach it with their unaided hand. Thus, the tool effectively extended the animals' reaching distance. In these monkeys, neuronal activity was recorded from the intraparietal cortex, where somatosensory and visual information is integrated. Neurons responding to both somatosensory and visual stimulation, namely 'bimodal neurons', were analysed (Figure 1).

Some of these neurons responded to somatosensory stimuli at the hand (Figure 1a), and to visual stimuli near the hand (Figure 1b). Furthermore, their vRF followed the hand when this was moved in space. Crucially, in some of these bimodal neurons the vRFs expanded to include the entire length of the tool, after the monkey had performed

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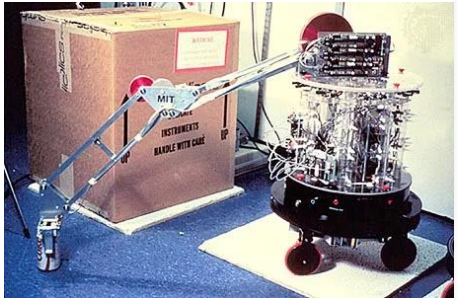
Three Grades of Embodiment

Mere Embodiment: The body is a passive tool controlled by reason.

Basic Embodiment: The body's dynamics and sensor placements actively influence actions.

Profound Embodiment: The system integrates body and environment into a unified whole.









“A **profoundly embodied** creature or robot is thus one that is highly engineered to be able to learn to make maximal problem-simplifying use of an open-ended variety of internal, bodily, or external sources of order”.

“Rather, they are *promiscuously* body-and-world exploiting. They are forever testing and exploring the possibilities for incorporating new resources and structures deep into their embodied acting and problem-solving regimes. They are the minds of **“natural-born cyborgs”**—of systems continuously renegotiating their own limits, components, data stores, and interfaces. On this account, the body is both critically important and **constantly negotiable**”

Thanks!



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