BODY SCHEMA UPDATES USING AN INTERACTIVE 3RD PERSON VIEW FOR VIRTUAL REALITY THERAPY

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OVERVIEW: An interactive virtual reality (VR) that enables an individual to observe his own body movements from a 3rd Person View, while real-time computer vision algorithms enable coherent motion-interactions with virtual multimodal objects, in a framework that integrates the perception-action-behaviour cycle, evinced to give a better perspective of the 'Body Schema', for use in experimental paradigms as well as VR Therapy related to motion disabilities.

THEORETICAL BASIS FOR VIRTUAL REALITY DESIGN

INTRODUCTION :

Recent findings have extended the classical view of the 'Body Schema' beyond the mere unconscious construct of proprioceptive signals – to multimodal information that include somato-sensory, auditory and visual modalities. Further, the real time update of the 'Body Image' is not just purely perceptual but also involves the space coding of action.

CORTICAL MOTOR ORGANIZATION :

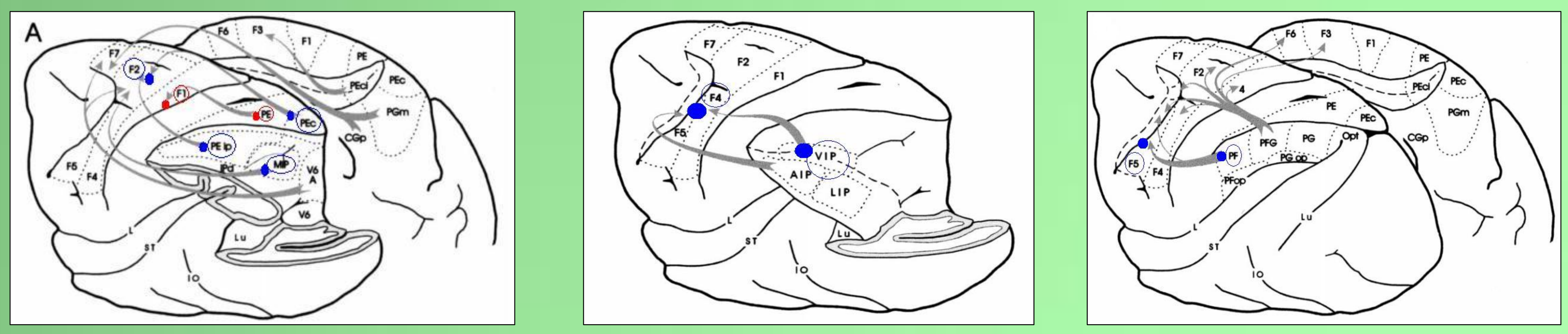
The naive representation of Motor Cortex Organization as Primary Cortex M1 and Supplementary Motor Area (SMA) has radically changed over the years. The latest view of cortical motor organization has been succinctly listed below *[Rizzolatti et al, 1998]*:

Parietal and Motor areas are connected reciprocally to form a series of specialized circuits working in parallel three of which are described below:

- Motor Cortex – is made up of anatomically & functionally distinct areas
- Posterior Parietal Lobule – within which each area is responsible for a particular aspect of sensory information processing. Along with the Motor Cortex, it has many arm, face and leg representations, over 2 distinct regions – Superior Parietal Lobule (**SPL)** and Inferior Parietal Lobule **(IPL)** that process both somato-sensory as well as visual inputs.
- The Posterior part of the SPL and IPL process visual information.
- The Anterior part of the SPL and IPL are related to somato sensory information and the integration of visual & somatosensory information respectively.

PARIETO FRONTAL CIRCUITS :

Each motor area has afferent connections with many parietal areas, with one of the connections being predominant. Similarly each parietal area is connected to several motor areas with only one dominant connection. Taking only the predominant fronto parietal circuits, specific sensory motor transforms of actions have been defined.



The Figure's above shows the circuits that were found relevant for the design of the Virtual Reality interface, to ensure their activation and engagement. These are described below :

1) PE – F1 circuit :

PE (BA 5) is known to be associated with the processing of proprioceptive information. *[Laquaniti et al]* found that the PE encodes the location of arm in space into body-centered coordinates. The function of PE-F1 appears to be to provide F1 area with location of body parts to execute certain movements. Apart from the predominant PE connection, the F1 area also receives connections from F2, F3, F4 and F5. F1 area is responsible for segmenting motion plans of other motor areas into elementary steps of motion. *[Porter and Lemon, 1993]*

2. INFERIOR AREA 6 ('Ventral Premotor Cortex Circuits')

2.1 VIP-F4 circuit :

The VIP-F4 circuit was found to be responsible to encode the peripersonal space and process object locations to launch an action towards them. *[Rizzolatti et al]*. Of particular interest is the VIP region in the intraparietal sulcus that receives visual projections of optical flow and motion *[Ungerleider and Desimone, 1986]* from the 'dorsal visual stream' as well as somatosensory information. VIP neurons can either be 1) purely visual or 2) bimodal (visual & tactile) *[Colby et al., 1993; Bremmer et al., 1997]*. Tactile Receptive Fields (tRFs) are located mainly on the face. Visual RFs are located in regions of the visual field corresponding to location of Tactile RFs, and they remain in the same location with reference to the body, regardless of gaze direction.

F4 : Unimodal and Bimodal neurons in the F4 regions were found to fire when reaching movements were made for or away from the body. *[Godschalk et al., 1981]* Unlike the VIP, bimodal neurons in F4 are typically tactile. The location of the Visual RF of bimodal neurons is independent of Gaze and remains anchored to the Tactile RF, when the body part associated with the Tactile RF is moved. Thus space in F4 is encoded in body centered coordinates *[Graziano et al., 1994; Fogassi et al., 1996]*.

2.2 PF-F5C circuit

F5C neurons, also called Mirror Neurons *[Gallese et al., 1996; Rizzolatti et al., 1996a]* have a distinct property for firing, when a person observes another performing an action similar to that encoded by the neuron-- underlining a cognitive role of the motor cortex in internal neuronal representations of actions.

3.SUPERIOR AREA 6 ('DORSAL PREMOTOR') CIRCUITS:

PEc/PEip-F2 dimple and MIP-F2 ventrorostral circuits

Monitoring and controlling arm movements during the transport phase of an arm to a target appears to be the main function of these circuits, with optical ataxia symptoms (due to damage in the superior parietal lobule) fitting well with the hypothesis.

Area PEip, in rostral part of the medial bank of intraparietal sulcus respond mostly to somato-sensory stimuli. *[Iwamura and Tanaka, 1996]* They are typically associated with arm movements, with activation being stronger when the arm extended is directionally projected *[Kalaska et al., 1990]* The PEc as well as MIP regions also use somatosensory and visual information to project to F2 which stores arm and leg movement representations.

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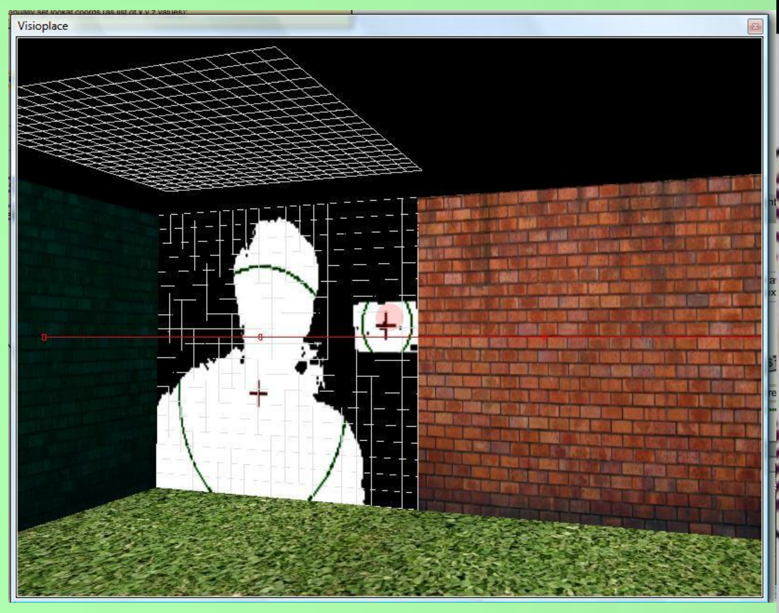
VIRTUAL REALITY DESIGN DISCUSSION

THIRD PERSON VIEW :

Tele-immersive systems and Video Games give us the idea of self image being extended into the virtual world. Studies using artificial visual probes on monkeys *[Maravita et al,2004]* have indicated that the Visual Receptive Field (VRF, of somatosensory RF located on the hand) were also formed around a mere visual image of the hand on a monitor. The size and position of the vRF also varied with modified representations of the hand image, suggesting that virtual representations of the hand were treated by the monkey as an extension of the self.

RESEARCH IMPLICATIONS:

Patients with sensory ataxia and other motion disabilities that involve a loss of proprioceptive knowledge about their own body centered coordinates would benefit from a 3rd Person Representation of themselves performing a motion task, as it clearly represents the location of their own arms with respect to a reference point. With body centered proprioceptive information and segmented motion happening in the PE-F1 Region, the 3rd Person View also provides the Mirror neuron activations required by the PF-F5C circuits for making congruence to stored action states, by observing 'another' self performing a motion. A thresholded binary video stream was used to render a modified self representation , to highlight structural aspects of the user's body rather than textural and facial features.



MOTION TRACKING and VR INTERACTION:

The Virtual Reality prototype developed was instilled with computer vision software modules to track the arm motions of the subject in real time, with the intention of providing access to the motion curve, and time taken for virtual target acquisition for use in assessme

Shown above is a basic implementation of a continuous adaptive mean filter , with a bounding box around the centroid which was manually chosen by assigning a colour value from the source video (webcam feed), to then track a blob, so corresponding motions (here the hand) of the user may be tracked in real time.

Another point tracking method was derived by using the Lucas-kanade method for calculating Optical Flow. Again a point on the body part is chosen manually, so optical flow is calculated for a few points in a locus area.

Motion of a user maybe mapped to physical interactive virtual objects and other modalities like audio. The visual or audio feedback from the virtual world as a patient moves his hand towards a specified target thus provides him with additional sensory inputs to enhance his proprioception.

FUTURE DIRECTIONS:

The interactive VR prototype described here was developed with a future objective of being an aid to understanding motion disabilities especially in a therapeutic clinical setting.

Of particular interest is the intermodal conflict of ataxia, where a mismatch in information received by proprioception from the impaired dorsal stream of bilateral occipito-parietal visual input results in disturbances in goal-directed movements.

The efficacy of using this 3rd Person View to improve a patient's proprioception regarding dynamic body schema with respect to a goal target has yet to be studied.

How can effective multimodal feedback and interactive visual objects be mapped along with the tracked motion of a patient's arm to correct and retrain goal-directed movements without causing any further cognitive load is another interesting question that this pilot aims to answer in future.

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