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Short communication

# A functional magnetic resonance imaging study of the body schema using full human line-drawing figures in an on-line verbal naming and localization task of single body part words

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**Abstract**

Naming and localization of individual body part words to a high-resolution line drawing of a full human figure was tested in a mixed-sex sample of nine right handed subjects. Activation within the superior medial left parietal cortex and bilateral dorsolateral cortex was consistent with involvement of the body schema which is a dynamic postural self-representation coding and combining sensory afference and motor efference inputs/outputs that is automatic and nonconscious. Additional activation of the left rostral occipitotemporal cortex was consistent with involvement of the neural correlates of the verbalizable body structural description that encodes semantic and categorical representations to animate objects such as full human figures. The results point to a highly distributed cortical representation for the encoding and manipulation of body part information and highlight the need for the incorporation of more ecologically valid measures of body schema coding in future functional neuroimaging studies.


*Keywords:* Face encoding; Face recognition; Body part naming; Body schema; Body structural description; Body image; Autotopagnosia; Right–left disorientation; Finger agnosia

The group of disorders that involve disturbances of the body schema include: autotopagnosia, finger agnosia, phantoms, right–left disorientation, and perhaps visuoimitative apraxia for meaningless gestures [8]. In the transition from egocentric coordinates to extrapersonal spatially defined targets a series of automatic and nonconscious transformations takes place in which cells in Brodmann's areas seven and five convert retinotopic to head- to trunk- to shoulder- and arm-centered coordinates [12]. Awareness of one's own body requires vestibular, kinesthetic, tactile, and visual stimuli and complexes of these stimuli as perceptions and cognitive processes. Perhaps the most compelling argument for a mental body image are "phantoms" [14]. Such preliminary studies point towards the current lack of comprehensive conceptual frameworks in which to understand these uniquely human abilities.

Classically two variants of the body schema disruption have been identified in which the body schema is both completely or partially lesioned constituting autotopagnosia and finger agnosia, respectively [8]. Pick first described autotopagnosia (AT) in 1908 in which the primary features of the disorder was a loss of spatial knowledge about one's body [18]. It involves problems in pointing to body parts on verbal command and to imitation (i) on the patient's own body; (ii) on the examiner's body; (iii) or on a manikin or picture. Of the dozen or so recorded cases in which AT has been found without confounding language, general spatial localization, or dementia, it has been most often associated with early onset left parietal neoplastic lesions [8].

Finger agnosia in contrast involves difficulty in recognizing, identifying, and naming the fingers of the hand and was first described by Gerstmann [11]. Gerstmann's syndrome consists of finger agnosia, agraphia, acalculia, and right–left disorientation. Gerstmann attributed the neurological substrate to left angular gyrus lesions in the transition to the second occipital gyrus. More recent high-resolution CT and MRI, and virtual-lesioning studies have unequivocally demonstrated the four elements of

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the syndrome in several well-described patients [8]. Gerstmann noted that all four of these symptoms require the "notion of finger sense" in the context of finger praxis, the decimal system, or right–left orientation's common use of the hands.

Whereas AT involves the left parietal lobule finger agnosia occurs equally in patients with both left and right parietal hemisphere lesions [13]. Recently a case of crossed AT was found in a 71-year-old with mild left hemiplegia and acute fluent aphasia as a consequence of a right temporoparietal lesion [9]. In the context of normal calculation, praxis, memory and attention the authors suggested that AT results from the lesion to the inferior parietal lobe of the language dominant hemisphere. This group also noted that the deficit was only found when the patient was requested to retrieve a conscious representation of a spatial model of the body.

Denburg and Tranel noted in 2003 that there is a "... marked paucity of theoretical frameworks within which the concept of body schema could be properly situated and interpreted ..." (pg., 172) [7]. Recently sequential and comprehensive normative psychometric and qualitative studies have begun and three distinct triply dissociated types of body representations have been identified by the PENN Cognitive Neurology group. The *body schema* is a dynamic postural representation coding and combining sensory afference and motor efference inputs/outputs and is largely automatic and nonconscious. The *body structural description* is an invariant coding of topological point-to-point configural maps specifying possible body part angles and relationships and has a strong spatial component although spatial problems per se cannot account for the disorder. Finally there is a linguistic element, the *body image*, which incorporates body part names, functions, and common associations with objects and/or tools and is verbal, conscious and lexciosemantic in nature [3,6,22].

Coslett and Schwoebel distinguished between the body schema, body structural description and the body image [22]. Body schema tasks were exemplified by hand imagery and action tasks [23] as well as hand laterality tasks [17]. Body structural description tasks included localization of isolated body parts; localization of tactile input; and matching of body parts by location. Body image tasks included matching body parts by function and matching of body parts to clothing and objects. Using the largest consecutive and unselected stroke patient group of its kind the PENN lab found that the linguistic body structural description and body image tasks were associated with left temporal lesions whereas automatic on-line body schema tasks were associated with dorsolateral prefrontal and superior parietal lesions [22].

Downing's MIT group discovered a region within the right lateral occipitotemporal cortex or the extrastriate body area (EBA) in 2001 that is selectively sensitive to whole human body parts compared to a range of other stimuli [10]. However, their task was nonverbal in contrast to this study's verbal task and did not involve location of parts with a full figure model. There appears to be a strong rationale for using complete human figures since it has both face and ecological validity in comparison with previous part-based and nonverbal perceptual tasks. Reed and Farah found in 1995 that when participants imitated a real human actor's poses proprioceptive information concerning their own body position facilitated visuospatial perception of the model's body positions [20]. The effects could not be attributed to a strategy or non-body based generalized spatial schema. Secondly the 'inversion effect' commonly held to index the modularity of the 'face processor' [24] has also been demonstrated for human figures whereas biomechanically implausible postures with body parts juxtaposed upon each other attenuated this body-inversion effect [21].

These inversion effects imply a specific neural module for the detection, recognition, identification of full human figures in addition to faces. The hypothesis of this experiment was that subjects successfully performing a body schema task in conjunction with verbalizable naming would demonstrate activation centered within the left parietal lobule compared to the control face processing tasks.

Nine right-handed subjects (four females, five males) of mean age 27 (S.D. = 9) participated in a single 20-min fMRI session. All subjects provided their written informed consent and the experiment was provided with institutional ethics approval under an experimental fMRI protocol. Five conditions included visual fixation (VF), face encoding (FE), face recognition (FR), and body part naming (BPN) and motor decision (MD). Stimuli were presented continuously at the rate of one item every 5 s and FE, FR, BPN, MD consisted of eight items in each of four 40 s blocks for a total of 128 experimental events. Four 40-s VF trials were also included as the baseline condition. FE and FR conditions were always run consecutively and the BPN, MD and VF blocks were run pseudorandomly. Accuracy and reaction time was measured with fiber optic response boxes [MRA Inc.: http://www.mra1.com] and recorded by Superlab Pro [*Cedrus*: http://www.superlab.com]. Images were back projected onto a wide angle field (60 cm wide × 50 cm height) blank screen at the front of scanner and visualized with a periscope mirror.

There were 32 single nonfamous FE stimuli placed amidst two isoluminant mosaics and there were 32 exemplars of familiar nonfamous FR stimuli placed amidst two novel not previously seen nonfamous distractor faces. There were also 32 instances of MD items and 32 different BPN items covering the entire body. With the BPN items both the left and right sides of the body were proportionally represented at randomly presented locations. All FE, FR, BPN and MD individual items were placed randomly in one of three lateralized positions arranged from left to right and these item by location instances were randomized across subjects such that hemifield of presentation was systematically controlled for (see Fig. 1).

FE and FR items were constructed from college yearbook photos and were included as loose task comparisons to check the accuracy and veracity of the functional neuroimaging paradigm using an entirely novel BPN task [4]. Each FE item was placed randomly in one of the three columns aligned left to right with two isoluminant mosaics constructed from the photos. The FE task required subjects to make a binary decision to the effect of "Press button 1 if the face is male and press button 2 if the face is female" [1]. In the FR task one of the 32 previously viewed target faces was placed randomly amidst two not previously viewed novel distracter faces. Subjects were prompted 'Which face is familiar?' requiring a three choice motor response