Affordances based k-TR Common Coding Pathways for Mirror and Anti-Mirror Neuron System Models

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Abstract

The *k*-TR theory to visual perception is a recent psychophysical theory that explains the processing of visual perception in humans towards the goal of object detection, recognition, grasping and manipulation through the notion of functional and grasp affordances. In this work, we postulate a new Brain Operating Model based on the k-TR theory and supported by various neuro-biological studies to accompany the observed psychophysics. The key components of the model include the Mirror Neuron System (MNS) and the Anti-Mirror Neuron System (AMNS).

Keywords: Affordances; brain operating model, schema theory

Introduction

In this paper, we build a Brain Operating Model to explain affordance-related perceptual processing in the brain. We also design a schema theory based on PHG anti-mirror neurons and the known affordance coding linkages (as noted above) of the PHG substrate, calling it the Anti-Mirror Neuron System (AMNS) and use it to explain various aspects of the k-TR Common Coding Theory. The various sub-schemas of AMNS such as the Object/Hand Perception Schema, Reach/Grasp Schema, Core Anti-Mirror circuit along with the various biological units catering to the schemas in terms of sub-tasks such as object affordance extraction, motor execution, hand motion detection etc. and their contributions are analyzed through simulations and validated through psychophysical tests that involve subject recall of concrete nouns based on observation of affordance executions with/without the target object, self-actuation without visual perception and solely based on touch and move-assist by an external agent, along with control tests and negative affordance coding linkages. These psychophysical tests demonstrate the contribution of various affordance features (observed/imagined, as well as both visual coding and touch/motor coding) with respect to object recognition or object identity label (concrete noun) association.

Hypotheses Proposals

Hypothesis 1: There exist mirror neuronal reverse linkages from dorsal to ventral pathway for decoding sensorimotor affordance cues

Hypothesis 2: The sensorimotor encodings (action-perception common code) carry affordance features as described by the *k*-TR theory (Varadarajan 2011)

Hypothesis 3: Suggestive recruitment and modulation of dorsal and ventral feature faculties occurs in an iterative refinement process

Hypothesis 4: The linkage between perception affordance features and motor affordance (observed/ego-actuated) features is an independent process (Molyneux's problem has a negative response) and key to visual object perception

Corollary 1: Linguistic association in Object Recognition depends on affordance features from visual perception

Hypothesis 5: Anti-mirror neurons act as interfaces or junctions through which physical/manipulation affordance features extracted from perception (observed/simulated) in the dorsal pathway is filtered to remove motor features and integrated with material affordances, affordance semantics and other local instance features leading to retrieval of both object category and object instance from memory.

Corollary 2: Anti-mirror neurons are responsible for generation of perceptual affordance encodings of objects.

Dorsal Pathway and Ventral Pathway

The dorsal stream essentially represents the 'Affordance' stream or the '*k*' layer stream, while the ventral stream largely represents 'TR' feature extraction. These two pathways are physiologically described as the ventral and dorsal streams in the brain. The ventral stream can be expected to processes fine-grained texture information (TR). Early models of this Two-Stream Hypothesis portrayed the dorsal and ventral pathways as being independent of each other. Newer models show multiple interconnections between the two. Yet these have largely focused on the dorsal pathway receiving input from the ventral stream and not other way around (esp v3).

Mirror Neurons

Mirror neurons have been proposed as fundamental mechanism for learning new actions through imitation of observed action-affordances. Since mirror neurons respond to both ego-action/affordance execution as well as perception (visual or other sensory) of execution of action/affordances by an external agent, they provide the physiological mechanism for perception/action-affordance coupling. Mirror neurons are found along both the dorsal as well as the ventral pathways.

Affordance based Brain Operating Model and Object Recognition/ Manipulation Schema

We hypothesize in this work that there exist unique reverse linkages from the dorsal stream to the ventral stream and an iterative exchange of information along the forward and

reverse linkages is responsible for increase in granularity and fidelity of output from the two streams. In other words, the theory on "how" an object is/is to be afforded (through grasping and task driven or functional manipulation and typically based on geometric shape and spatial analysis - key processing done in the dorsal pathway) provides cues to recruit layers that enhance the extraction of object relevant features and parameters that determine "what" the object is. We further hypothesize that these cues represent sensorimotor encodings that contain affordance features (from *k*-TR) theory. For example, the first iteration from the dorsal to the ventral pathway could encode for attentional modulation based on motion, bottom-up affordance aberration saliencies and task driven top down affordance modulation. On the other hand the first iteration from the ventral to the dorsal pathway could encode material (frequency content analysis) affordances. We hypothesize here that the encodings are sensorimotor in nature and depend on observed/actuated motor, as well as affordance features from perception (primarily visual) along with the transformation from perception features to motor features playing a key role. A corollary from the above hypothesis is that linguistic association or object category labeling, which is an essential sub-process in object recognition should also employ affordance features from visual perception, since these are most dominant discriminative features for recognition. Direct support for the corollary comes from the recent breakthrough work from Just et al. (2010). The developed Brain Operating Model along with the sub-regions of the brain that compose the affordance extraction schema as well as the forward-reverse connections between the dorsal and ventral pathways are demonstrated in figure 1a. The various schemas associated with the brain regions interacting with the model are shown in the figure 1b.

Anti-Mirror Neurons and Anti-Mirror Neuron System (AMNS)

Besides the canonical F5 neurons that respond to ego-affordance execution and mirror neurons that respond to both ego and exo-affordance execution, there are also anti-mirror neurons that are in a excitatory state only in response to exo-affordance execution and accompanying linguistic association in the form of entities involved in the affordance execution. Anti-mirror neurons are found in the Parahippocampal Gyrus and additional neurons with similar function in the Entorhinal cortex. It can be hypothesized here that anti-mirror neurons might be interface or junction through which physical/manipulation affordance features extracted from perception (observed/simulated) in the dorsal pathway is filtered to remove motor features and integrated with material affordances, affordance semantics and other instance features leading to retrieval of both object category and object instance from memory.

The validity of the proposed Brain Object Perception Model is also supported by Anti-Mirror Neuron System (AMNS) Psychophysical tests (Varadarajan 2013). The contributions of the various modules in AMNS were analyzed through simulations and validated through psychophysical tests that involve subject recall of "concrete nouns" based on observation of affordance executions with/without the target object, self-actuation without visual perception and solely based on touch and move-assist by an external agent, along with control tests and negative affordance coding linkages. These psychophysical tests demonstrated the contribution of various affordance features (observed/imagined, as well as both visual coding and touch/motor coding) with respect to object recognition or object identity label (concrete noun) association. On tests for recall of 20 samples from 50 categories across 17 test subjects, direct recall yielded an accuracy of 34%, while affordance aided recall yielded and negative affordance primed recall yielded rates of 62% and 21% with object and 60% and 2% without object. Hence, affordances were found to be key to recognition. The difference between observed (exo-) and self (ego-) affordance execution were minimal from the standpoint of recognition of objects in simulated affordance sequences.

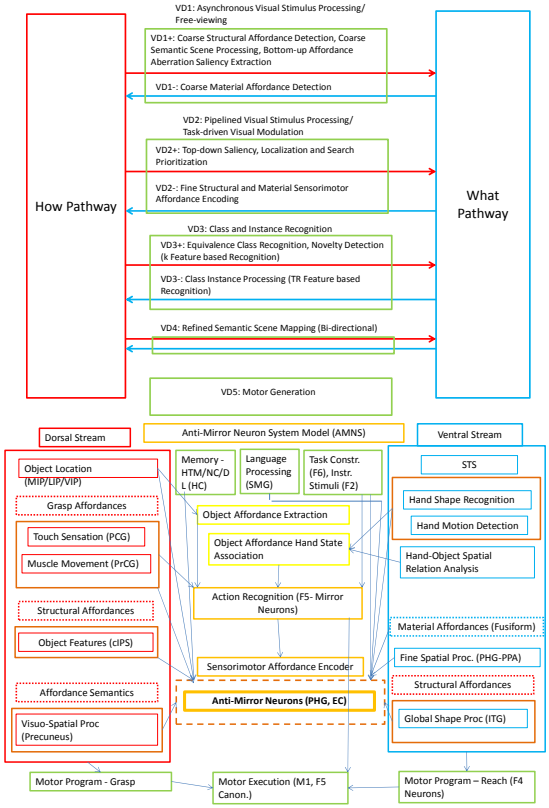

Figure 1a (top). Brain Operating Model and 1b (bottom). Schemas

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