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Commentary

Indirect cognitive control through top-down activation of perceptual symbols

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In classical, ‘‘non-embodied’’ approaches to mental representation, human action is construed as the output of a centralized system that is heavily involved in forming an internal model of the world, one composed of ‘‘amodal’’ symbols that, for combinatorial and computational purposes (Pylyshyn, 2002), do not retain any of the properties of the sensorimotor states that gave rise to them (Arkin, 1998; Barsalou, 1999, 2008; Kosslyn, Thompson, & Ganis, 2006). In these frameworks (e.g., Burgess & Lund, 1997; Landauer & Dumais, 1997), knowledge is represented by truth tables, feature lists, and elements as arbitrary as those of computer memory (binary digits). In unpredictable environments, such centralized systems require tremendous computational power to continually update their amodal model of the world (Arkin, 1998). This error-prone and time-consuming translational process is unnecessary in modal systems (Arkin, 1998; Markman & Dietrich, 2000), for action-relevant information is already available in the environment or is *embodied* in representations that maintain properties of the sensorimotor states that gave rise to them (e.g., *perceptual symbols*; Barsalou, 1999, 2008; Farah, 2000). As Pickering and Garrod propose, this advantage of speed and accuracy renders embodiment of form and meaning as mechanisms that may explain how the fast and intricate cognitive processes of dialogue can be carried out so effortlessly.

Building on their framework, we consider how embodiment of meaning may illuminate, not only how dialogue is accomplished between individuals but also how a heretofore unidentified form of internal dialogue is achieved within the nervous system. As explained below, we propose that it is through top-down activation of perceptual symbols that *‘‘controlled*’’ *conscious pathways* can interact with what have been regarded as the *unconscious action pathways* (Goodale & Milner, 2004; Lieberman, 2007; Morsella, 2005; Strack & Deutsch, 2004), such as those of encapsulated affective/incentive response systems (LeDoux, 1996; Morsella, 2005; O"hman & Mineka, 2001). We also propose that, in dialogue, affective/incentive states may be elicited in others in a similar fashion—by activating perceptual symbols that, as *releasers* (Tinbergen, 1952), trigger desired states.

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Indirect Cognitive Control

Few cognitive processes can be influenced by *direct cognitive control* (Bargh & Morsella, 2008; Morsella, 2005; O"hman & Mineka, 2001), which is perhaps best exemplified by one's ability to immediately control thinking (or imagining) and the movements of a finger, arm, or other skeletal muscle effector (Morsella, Krieger, Rizzo-Fontanesi, & Bargh, 2007). Interestingly, each of these kinds of processes requires the activation of perceptual-like representations, one for constituting mental imagery (Farah, 2000) and the other for instantiating *ideomotor* mechanisms (Hommel, Müsseler, Aschersleben, & Prinz, 2001). In imagination, mental imagery, and attentional processing, top-down control can suppress or enhance the activation of representations (cf., Gazzaley, Cooney, Rissman, & D'Esposito, 2005). Substantial neural evidence reveals that similar modality-specific regions are activated when one is thinking (Kosslyn et al., 2006), imagining (Farah, 2000), hallucinating (Ffytche, 2000), or speaking about the same thing (Martin, 2001; Pulvermuller, 2005). As noted by Pickering and Garrod, there is behavioral evidence that, in dialogue, perceptual symbols such as the shape of an object are activated during comprehension (Zwaan, Stanfield, & Yaxley, 2002).

Unlike this kind of direct control, it seems that one may not be able to directly influence one's affective/incentive state at will—one cannot with the snap of a finger make oneself frightened, happy, angry, sad, or excite a desired appetitive state (e.g., being hungry) if the adequate conditions are absent. Although direct control cannot activate affective/incentive states (O"hman & Mineka, 2001), it is possible to indirectly stimulate them by activating perceptual symbols that can then trigger the neural processes responsible for these states. This slower and more effortful form of control illustrates how a system with limited cognitive control—one that can directly activate only, say, perceptual-like representations—can still influence the functioning of otherwise encapsulated processes (Morsella & Krauss, 2004).

Conscious and Unconscious Action Systems

Goodale and Milner (2004) report neurological cases in which there is a dissociation between action and conscious perception. Patient D.F., who suffered from visual form agnosia, was incapable of reporting the orientation of a tilted slot (e.g., tilted 60 degrees), but could nonetheless negotiate the slot accurately when inserting an object into it. Along with other findings regarding the dichotomy of controlled versus automatic processes (Lieberman, 2007; Strack & Deutsch, 2004) and perception–action dissociations (see review in Westwood, 2009), this led to the view that there are distinct systems/pathways for conscious visual perception (situated ventrally) and unconscious action (situated dorsally). There is also substantial evidence that emotional systems can be activated, and influence action, unconsciously. For instance, fear conditioning is mediated by modularized nuclei in the amygdala of the midbrain that receive polysensory information from afferent pathways different from those feeding the ventral perception pathway, which is associated with conscious processing and self-report (Lavond, Kim, & Thompson, 1993; LeDoux, 1996; Olsson & Phelps, 2007). Moreover, subliminal stimuli (O"hman & Mineka, 2001; Pessiglione et al., 2008), and the unconscious ''suppressed image'' during binocular rivalry (Williams, Morris, McGlone, Abbott, & Mattingley, 2004), can influence behavior and activate nuclei in the brain that are involved in action-related emotional processing.

Mandatory Inputs and Mandatory Pathways

Evidence suggests that propositional (amodal) representations such as those of language do not lead to the same kinds of emotional effects and forms of affective learning as perceptual stimuli (LeDoux, 1996). Olsson and Phelps (2004) demonstrated that, through vicarious classical conditioning, subjects can acquire a learned fear response toward a subliminal stimulus by perceiving someone else receive a shock after being presented with that stimulus. However, simply telling subjects about the contingency between stimuli did not lead to this form of vicarious conditioning to subliminal stimuli. This suggests that the phylogenetically old systems mediating fear conditioning may not understand language (at least not very well), though they can process the meaning of basic perceptual events: ''Classical conditioning and observational learning . . . might be supported by an evolutionary old system that predates the emergence of language'' (Olsson & Phelps, 2007, p. 1099). However, in the absence of the appropriate external stimuli, this system can be activated indirectly, by the effortful activation of the appropriate perceptual symbols (e.g., remembering scenes from a scary movie).

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Let us take the example of trying to make oneself hungry in the absence of food stimuli. As known by *method* actors, who actually make themselves angry, sad, or fearful in order to act angry, sad, or fearful, one way to make oneself hungry is to imagine tasty food. Top-down processing directly activates, not the circuits responsible for hunger, but perceptual symbols, which in turn stimulate the appetitive system in a manner similar to the way that external stimuli would. This process is slow and cognitively taxing, because purposefully activated perceptual symbols tend to be transient, and activating them is effortful (Farah, 2000).

Neuroanatomically, activating the hunger system indirectly through perceptual symbols makes a great deal of sense, because *low-level perceptual representations (whether visual, olfactory, auditory, or haptic) exist at an early stage of processing that happens to be shared by both "action" and "perception" pathways* (Goodale & Milner, 2004), as illustrated in Figure 1. In this and other situations, perceptual symbols are the "common currency" of many systems, only some of which are related to consciousness/controlled processes. In conclusion, we propose that the conscious, perceptual system is the *mandatory pathway* in which high-level top-down representations and linguistic representations are "cashed in" (thereby solving "the grounding problem," Harnad, 1990) to function as releasers, releasers that can activate emotional processing and basic drives. This "common currency" pathway furnishes a key by which top-down control could indirectly unlock and stimulate the action pathways of incentive and emotional systems (and perhaps of other systems as well) that would otherwise be encapsulated processes. This does not imply that top-down processes are incapable of turning off or otherwise disrupting emotional or incentive processes. It has been documented that the frontal cortex can directly inhibit activities of the amygdala (cf., Cunningham et al., 2004). In principle, there are important differences between the mechanisms required for activation and deactivation (Gazzaley & D'Esposito, 2007), as disruption of any process can usually be instantiated in more ways than activation (Morsella, Larson, & Bargh, in press).

Knowledge representation through perceptual symbols may provide voluntary high-level executive processes with a greater range of influence over involuntary nervous activities, primarily because of the broadcasting properties of the particular stage-of-processing at which symbols happen to reside. How people learn to use indirect control is an interesting question for metacognition research. It may be that high-level frontal cortex representations such as *make oneself hungry* (cf., Grafman & Krueger, 2009) are already intimately associated with the lower-level perceptuo-semantic representations of food stimuli because, as proposed in Pickering and Garrod's framework, the latter happen to constitute the semantics of

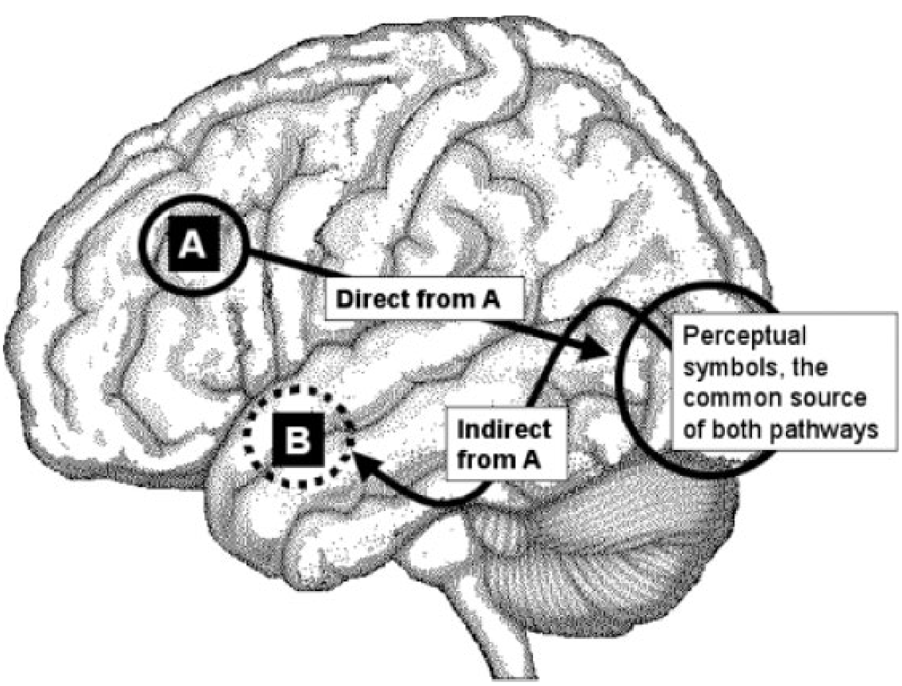

Figure 1. Through indirect cognitive control, control regions of the frontal cortex (A) stimulate incentive or emotional neural systems (B), such as nuclei in the amygdala or hypothalamus, but only indirectly, through the *mandatory pathway* involving activation of perceptual symbols

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the former (Barsalou, 2008; Pulvermuller, 2005). Thus, activation may simply flow backwards from highly abstract representations in frontal control regions of the brain to the perceptuo-semantic stage of processing that, in virtue of being the common source of many pathways, can influence multiple systems simultaneously.

The Mandatory Pathway in Communication

Building on the Pickering and Garrod framework, we propose that the perlocutionary goal of eliciting an affective/incentive state in an addressee may be met by activating in the addressee those perceptual symbols that, as releasers, trigger the desired states. With some effort, one can in verbal and nonverbal communication make listeners hungry, angry, or experience another affective/incentive state (Kosslyn et al., 2006). From this standpoint, activation of the mandatory pathway renders it impolite to make noxious sounds or utter disgusting words (e.g., insect names) during dinner, because of the states they elicit. Such elicitations seem to depend on both the degree of activation of perceptual symbols (Farah, 2000) and what may be construed as the ''perceptual'' depth-of-processing of the meaning of the utterance (Paivio, 1979). Poets are well aware that it is through concrete language that readers are moved: ''Ezra Pound punched the wall'' has greater dramatic effect than ''Ezra Pound was angry.'' Similarly, the utterance ''make yourself hungry'' is not as successful in making others hungry as perceptually rich descriptions of coveted foods, and the utterance ''spider'' is more likely to elicit disgust than ''arthropod,'' because, as a basic-level category, the former is perceptually richer than the latter (Markman, 1999). ''It remains unclear how modal information can represent abstract or inter-modal content; see potential solution in Barsalou, 1999.)''

It becomes an empirical question whether language fails to lead to the kind of vicarious conditioning afforded by observational learning only because language comprehension yields ''faint'' activations of perceptual symbols (Boroditsky & Ramscar, 2002; Zwaan, 2008). If so, communication should elicit normal conditioning if subjects, through extensive and vivid mental imagery, perceptually ''cash in'' the narrative. Alternatively, a lack of normal conditioning may reflect that linguistic–semantic knowledge is simply distinct from sensorimotor knowledge, which would cast doubt on Pickering and Garrod's framework and would coincide with some neuropsychological evidence. For example, it is unclear whether lesions of action-related brain regions do in fact lead to impairments regarding the semantic knowledge of action: Patients suffering from deficits due to brain lesions can show impairments in the way they use certain objects but can nonetheless name those objects, or even recognize the pantomimes associated with those objects, without difficulty (Mahon & Caramazza, 2008).

Hence, it must be determined whether the difference between the activation of perceptual symbols by natural experience or by dialogue is quantitative (the faintness hypothesis) or qualitative, as proposed by Mahon and Caramazza (2008). Resolving this issue is relevant only to *inter*-cerebral communication (when one manipulates the mandatory pathways of others) and does not bear on how embodiment of meaning, combined with indirect cognitive control, may resolve a long-standing conundrum regarding large-scale *intra*-cerebral communication (cf., Fries, 2005).

In conclusion, Pickering and Garrod emphasize how embodiment of meaning can explain aspects of the facility of dialogue. We have explored how having knowledge represented in certain ways (modally) and at certain stages of processing (those shared by many systems) may also explain how communication—and control of encapsulated affective/incentive systems—is achieved within and between nervous systems.

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