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The Primary Function of Consciousness in the Nervous System*

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Abstract

Morsella E, Krieger SC, Rizzo-Fontanesi S, Bargh JA. The Primary Function of Consciousness in the Nervous System. ARBS Annu Rev Biomed Sci 2007;9:37-40. The *integration consensus* proposes that consciousness integrates activities in the nervous system that would otherwise be independent, but it fails to specify which kinds of integration require consciousness. By contrasting the task demands of consciously-penetrable processes (*e.g.*, pain) and consciously-impenetrable processes (*e.g.*, pupillary reflex and peristalsis), Supramodular Interaction Theory proposes that consciousness is required to integrate agentic, high-level systems that are vying for (specifically) skeletomotor control, as described by the principle of *parallel responses into skeletal muscle* (PRISM). Thus, consciousness functions above the level of the traditional module to permit cross-talk among specialized, and often multi-modal, systems.

Keywords: Consciousness, function of consciousness, integration consensus, mind-body problem

Consciousness (the elusive phenomenon falling under the rubrics of ‘awareness’, ‘sentience’, or ‘subjective experience’) is said to be possessed by an organism if there is *something it is like* to be that organism — something it is like, for example, to be human and experience pain or yellow afterimages (Nagel, 1974). We address what consciousness *is* by examining why one is aware of some nervous system events (*e.g.*, pain, urge to breathe), but not others (*e.g.*, intersensory interactions, peristalsis, pupillary reflex). Thus, we propose that consciousness serves a basic function in the nervous system that is intimately related to the actions of the skeletal muscle system.

* This article is based on a theory introduced in *Psychological Review* (Morsella, 2005)

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The *integration consensus* proposes that consciousness somehow integrates neural activities and information-processing structures that would otherwise be independent. Thus, consciousness allows diverse kinds of information to be gathered in some sort of global workspace (see reviews in Baars, 2002; Merker, 2007; Morsella, 2005). However, it is unclear which kinds of information must be distributed and integrated in a conscious manner and which kinds can be distributed and integrated unconsciously. Obviously not all kinds of information are capable of being distributed globally (*e.g.*, neural activity related to reflexes, vegetative functions, unconscious motor programs, and low-level perceptual analyses) and many kinds can be disseminated and combined with other kinds without conscious mediation, as in the many cases of intersensory processing. For example, the McGurk effect (McGurk & MacDonald, 1976) involves interactions between visual and auditory processes: an observer views a speaker mouthing 'ba' while presented with the sound 'ga'. Surprisingly, the observer is unaware of any intersensory interaction, perceiving only 'da'. Consistent with the view that consciousness is associated with only a subset of all brain regions and processes (Merker, 2007), these phenomena demonstrate that consciousness is unnecessary to integrate information from different modalities. Hence, which kinds of integration require consciousness?

Supramodular Interaction Theory (SIT; Morsella, 2005) addresses this issue by contrasting the task demands of *consciously-impenetrable* processes (*e.g.*, pupillary reflex, peristalsis, intersensory conflicts, and 'vegetative' actions) and *consciously-penetrable* processes (*e.g.*, pain, urge to breathe). Specifically, SIT contrasts interactions that are consciously impenetrable with *conscious conflicts*, a dramatic class of conscious interactions between different information-processing systems. Conscious conflicts are a basic part of the human experience. For example, when one experiences the common event of holding one's breath underwater, withstanding pain, or suppressing elimination behaviors, one is simultaneously conscious of the inclinations to perform certain actions and of the inclinations to not do so. SIT builds on the integration consensus by proposing that consciousness is required to integrate information, *but* only certain kinds of information. Specifically, it is required to integrate information from specialized, high-level (and often multi-modal) systems that are unique in that they may conflict with skeletal muscle plans, as described by the principle of *Parallel Responses into Skeletal Muscle* (PRISM). These *supramodular* systems are defined in terms of their 'concerns' (*e.g.*, bodily needs) rather than in terms of their sensory afference (*e.g.*, visual, auditory).

Operating in parallel, supramodular systems may have different operating principles, concerns, and phylogenetic histories (Morsella, 2005). For example, an *air-intake* system has the skeletomotor tendencies of inhaling; a *tissue-damage* system has those of pain withdrawal; an *elimination system* has those of micturating and defecating; a *food-intake* system has those of licking, chewing, and swallowing. Thus, each system can influence action directly and unconsciously, but it is only through consciousness that they can influence action collectively, as during a conscious conflict (*e.g.*, when carrying a scorching plate or holding one's breath).

Supramodular Conflict

Supramodular systems are inflexible in the sense that, without consciousness, they are incapable of taking information generated by other systems into account. For example, the tissue-damage system is 'encapsulated' in the sense that it will protest damage even when the action engendering the damage is lifesaving. According to SIT, one can breathe unconsciously, but consciousness is required to suppress breathing. Similarly, one can unconsciously emit a pain-withdrawal response, but one cannot over-ride such a response for food or water concerns without consciousness. Similar classes of conflict involve air-intake, food-intake, water-intake, sleep onset, and the various elimination behaviors.

PRISM

Figuratively, there are multiple systems trying to control the same 'steering wheel' (i.e., the skeletal muscle system) in the nervous system. For example, expressing (or suppressing) inhaling, blinking, pain withdrawal, micturating, and defecating all involve, specifically, skeletal muscle plans. Accordingly, regarding processes such as digestion, one is conscious of only those phases requiring coordination with skeletomotor plans (*e.g.*, chewing, defecating) and none of those that do not (*e.g.*, peristalsis). Conversely, no skeletal muscle plans are directly involved in unconscious processes such as the pupillary reflex, peristalsis, bronchial dilation, and vasoconstriction (all involving smooth muscle); and heart rate regulation (involving cardiac muscle). Regarding a process such as digestion, one is conscious of only those phases requiring coordination with skeletal muscle plans (*e.g.*, chewing). The PRISM acronym is conceptually related to the principle, for just as a prism combines different colors to yield a single hue, consciousness culls simultaneously activated tendencies to yield adaptive skeletomotor action.

Why Skeletal Muscles are 'Voluntary' Muscles: since the nineteenth century it has been known that, though often functioning unconsciously (as in blinking and breathing), skeletal muscle is the only effector that can be consciously controlled, but why this is so has never been explained. SIT introduces a reinterpretation of this age-old fact: *skeletomotor actions are at times 'consciously mediated' because they are directed by multiple, encapsulated systems that, when in conflict, require consciousness to yield adaptive action.* Accordingly, incompatible skeletomotor intentions (*e.g.*, to point right *and* left, to eat *and* not eat, to inhale *and* not inhale) produce strong, systematic changes in consciousness. For example, in a paradigm in which participants are trained to introspect conflict-related aspects of cognition during an interference task and then introspect the same 'thing' while sustaining compatible intentions (*e.g.*, pointing left with a given finger *and* vibrating that finger) and incompatible intentions (*e.g.*, to point left *and* right with the same finger), participants reported stronger systematic changes in subjective experience when sustaining incompatible than compatible skeletomotor intentions, even though participants were always in a motionless state (Morsella *et al.*, 2006). Moreover, it has been demonstrated that, of the traditional forms of flanker interference in variants of the classic Eriksen flanker task (*e.g.,* stimulus interference and response interference; Eriksen & Schultz, 1979), response interference produces the strongest subjective effects (Morsella *et al*., 2007). This is consistent with the observation that conflicts occurring at perceptual levels of processing (*e.g.*, intersensory conflicts as in ventriloquism) are not as subjectively taxing as those occurring at response selection levels of processing, whether in interference tasks, approach-avoidance conflicts (Livnat & Pippenger, 2006), or the delay of gratification (Metcalfe & Mischel, 1999). Figuratively speaking, people tend not to experience any mental strife while watching a ventriloquist or being subjected to the McGurk effect, but such is apparently not the case while they perform interference tasks or exert self-control.

PRISM also correctly predicts that certain aspects of the expression (or suppression) of emotions (*e.g.*, aggression, affection), reproductive behaviors, parental care, and addiction-related behaviors should be coupled with consciousness, for the action tendencies of such processes may compromise skeletal muscle plans. Conversely, one will never be conscious of activities such as peristalsis, for they do not require communication across systems in order to yield adaptive action. Consistent with this approach, automatic actions (*e.g.*, reflexive swallowing) involve substantially fewer brain regions than their intentional counterparts (*e.g.*, volitional swallowing; Kern *et al.*, 2001). In summary, SIT explains why some processes are conscious while others are not, and why skeletal muscle is the only muscle that is controlled 'voluntarily'. Building on the integration consensus, SIT allows one to appreciate that not all kinds of integration involve consciousness and that conscious and unconscious processes may be distinguished by the nature of the effectors involved. Given these developments, the time has come for neuroscience to isolate the neuroanatomical regions that embody supramodular cross-talk and to illuminate the physical events that render it conscious.

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