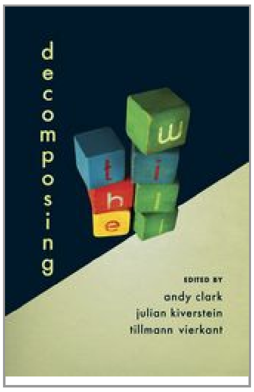

Decomposing the Will

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Voluntary Action and the Three Forms of Binding in the Brain

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[–] Abstract and Keywords

Historically, consciousness has been linked to the highest of intellectual functions. For example, investigators have proposed that the primary function of consciousness pertains to language, "theory of mind," the formation of the self, semantic processing, the meaningful interpretation of situations, and simulations of behavior and perception. This chapter determines what consciousness is for by focusing on the primary, basic role that consciousness contributes to action production. It approaches this question from a nontraditional perspective—by working backward from overt voluntary action to the underlying central processes. This approach reveals that the primary function of consciousness (to yield adaptive skeletomotor action by instantiating a unique form of integration, or "binding") is more basic-level than what has been proposed. In addition, it reveals that "volition" and the skeletal muscle output system are intimately related to this

primary function of consciousness.

Keywords: consciousness, voluntary action, volition, intellectual functions, semantic processing, interpretation, skeletomotor action

Historically, consciousness[1] has been linked to the highest of intellectual functions. For example, investigators have proposed that the primary function of consciousness pertains to language (Banks, 1995; Carlson, 1994; Macphail, 1998), "theory of mind" (Stuss & Anderson, 2004), the formation of the self (Greenwald & Pratkanis, 1984), cognitive homeostasis (Damasio, 1999), the assessment and monitoring of mental functions (Reisberg, 2001), semantic processing (Kouider & Dupoux, 2004), the meaningful interpretation of situations (Roser & Gazzaniga, 2004), and simulations of behavior and perception (HessloW, 2002). In this chapter, we address the question regarding *what consciousness is for* by focusing on the primary, basic role that consciousness contributes to action production. We approach this question from a nontraditional perspective—by working backward from overt voluntary action to the underlying central processes (Sperry, 1952). This approach reveals that the primary function of consciousness (to instantiate a unique form of integration, or "binding," for the purpose of adaptive behavior) is more basic-level than what has been proposed and that "volition" and the skeletal muscle output system are intimately related to this primary function of consciousness. It is important to emphasize that our question pertains to what consciousness is for (e.g., with respect to action); it is not about what consciousness *is* (neurally or physically) or about the nature of the neural processes associated with it. (With respect to biological systems, *how* and *why* questions are fundamentally different from *what for* questions; Lorenz, 1963; Simpson, 1949.)

Theories granting high-level, multifaceted functions to consciousness often fail to consider the empirical question, Why is consciousness associated with only some of the many kinds of processes/representations that science tells us must exist within our nervous system? In the field, there is a consensus that it is associated with only a subset of all brain regions and processes (Merker, 2007; see review in **(p.184)** Morsella, Krieger, & Bargh, 2009). To isolate the primary function of consciousness and identify its role in voluntary action, one must first appreciate all that can be accomplished unconsciously in the nervous system.

Unconscious Action and Unconscious Processing

Regarding unconscious action, there are several kinds of actions that can occur while subjects are in what appears to be an unconscious state (Laureys, 2005; see review in Morsella & Bargh, 2011). Actions such as automatic ocular pursuit and some reflexes (e.g., pupillary reflex) can occur in certain forms of coma and persistent vegetative states (Klein, 1984; Laureys, 2005; Pilon & Sullivan, 1996). In addition, licking, chewing, swallowing, and other behaviors can occur unconsciously once the incentive stimulus activates the appropriate receptors (Bindra, 1974; Kern et al. 2001). Research on the kinds of "automatisms" exhibited during epileptic seizures, in which the patient appears to be unconscious or to not have any conscious control, has revealed unconsciously mediated stereotypic actions such as simple motor acts (Kutlu et al., 2005), spitting

(Carmant et al., 1994), humming (Bartolomei et al., 2002), and oroalimentary automatisms (Maestro et al., 2008). Even written and spoken (nonsense) utterances (Blanken, Wallesch, & Papagno, 1990), sexual behaviors (Spencer et al., 1983), and rolling, pedaling, and jumping (Kaido et al., 2006) can be found to occur in a reflexive manner during seizures. There are cases in which, during seizures, patients sing recognizable songs (Doherty et al., 2002) or express repetitive affectionate kissing automatisms (Mikati, Comair, & Shamseddine, 2005). In narcolepsy (Zorick et al., 1979) and somnambulism (Plazzi et al., 2005; Schenk & Mahowald, 1995), there, too, are complex, unconscious behaviors (e.g., successfully negotiating objects).

Convergent evidence for the existence of unconscious action is found in neurological cases in which, following brain injury in which a general awareness is spared, actions become decoupled from consciousness, as in *blindsight* (Weiskrantz, 1997), in which patients report to be blind but still exhibit visually guided behaviors. Analogously, in *blind smell* (Sobel et al., 1999), people can learn to associate odorants with certain environments (e.g., a particular room), even though the concentration of odorants presented during learning was consciously imperceptible. Similarly, in *alien hand syndrome* (Bryon & Jedynak, 1972), *anarchic hand syndrome* (Marchetti & Della Sala, 1998), and *utilization behavior syndrome* (Lhermitte, 1983), brain damage causes hands and arms to function autonomously. These actions include relatively complex goal-directed behavior (e.g., the manipulation of tools; Yamadori, 1997) that are maladaptive and, in some cases, can be at odds with a patient's reported intentions (Marchetti & Della Sala, 1998). In addition, Goodale and Milner (2004) report neurological cases in which there is a dissociation between action and conscious perception. Suffering from visual form agnosia, patient D.F. was incapable of reporting the orientation of a tilted slot but could nonetheless negotiate the slot accurately when inserting an object into it.

Theorists have concluded from these findings that there are two different cortical visual pathways that are activated in the course of perception, a dorsal pathway that supports actional responses ("what to do") and a ventral pathway that supports **(p.185)** semantic knowledge regarding the object ("what it is"; see review in Westwood, 2009). Mounting evidence suggests that it is the dorsal (actional) system that operates outside of conscious awareness, while the operation of the ventral system is normally associated with awareness (Decety & Grèzes, 1999; Jeannerod, 2003).

Findings regarding perception-action dissociations corroborate what motor theorists have long known—that one is unconscious of the motor programs guiding action (Rosenbaum, 2002). In addition to action slips and spoonerisms, highly flexible and "online" adjustments are made unconsciously during an act such as grasping a fruit. For several reasons (see treatments of this topic in Gray, 2004; Grossberg, 1999; Rosenbaum, 2002), one is unconscious of these complicated programs that calculate which muscles should be activated at a given time but is often aware of the proprioceptive and perceptual consequences of these programs (e.g., perceiving the hand grasping; Gray, 2004; Gottlieb & Mazzoni, 2004; Helen and Haggard, 2005). In short, there is a plethora of findings showing that one is unconscious of the adjustments that are made "online" as one reaches for an object (Fecteau et al., 2001; Heath et al., 2008; Rossetti, 2001). Many experimental tricks are based on the fact that one has little if any conscious access to motor programs. In an experiment by Fourneret and Jeannerod (1998), participants were easily fooled into thinking that their hand moved one direction when it had actually moved in a different direction (through false feedback on the computer display).

In conclusion, there is substantial evidence that complex actions can transpire without conscious mediation. At first glance, these actions are not identifiably less flexible, complex, controlling, deliberative, or action-like than their conscious counterparts (Bargh & Morsella, 2008).

Regarding unconscious processing, "supraliminal" (consciously perceptible) stimuli in our immediate environment can exert forms of unconscious "stimulus control," leading to unconscious action tendencies. Consistent with this standpoint, findings suggest that incidental stimuli (e.g., hammers) can automatically prepare us to physically interact with the world (Tucker & Ellis, 2004; see neuroimaging evidence in Grèzes & Decety, 2002; Longcamp et al., 2005). For instance, perceiving a cylinder unconsciously increases one's tendency to perform a power grip (Tucker & Ellis, 2004). In addition, it has been shown that, in choice response time tasks, the mere presence of musical notation influences the responses of musicians but not of nonmusicians (Levine, Morsella, & Bargh, 2007; Stewart et al. 2003). Consistent with these findings, unconscious action tendencies are readily evident in classic laboratory paradigms such as the Stroop task[2] (Stroop, 1935) and the flanker task (Eriksen & Schultz, 1979).

In studies involving supraliminal priming of complex social behavior, it has been demonstrated that many of our complex behaviors occur automatically, determined by causes far removed from our awareness. Behavioral dispositions can be influenced by covert stimuli—when presented with supraliminal words associated with the stereotype "old," people walk slower (Bargh, Chen, & Burrows, 1996); when presented with stimuli associated with the concept "library," people make less noise (Aarts & Dijksterhuis, 2003); and when primed with "hostility," people become more aggressive (Carver et al., 1983). These effects have been found not only with verbal stimuli that are semantically related to the goal (as in many studies) but also with material objects. **(p.186)** For example, backpacks and briefcases prime cooperation and competitiveness, respectively (Kay et al., 2004); candy bars prime tempting hedonic goals (Fishbach, Friedman, & Kruglanski, 2003); dollar bills prime greed (Vohs, Mead, & Goode, 2006); scents such as cleaning fluids prime cleanliness goals (Holland, Hendriks, & Aarts, 2005); sitting in a professor's chair primes social behaviors associated with power (Chen, Lee-Chai, & Bargh, 2001; Custers et al., 2008); control-related words prime the reduction of prejudice (Araya et al., 2002); and the names of close relationship partners (e.g., mother, friend) prime the goals that those partners have for the individual as well as those goals the individual characteristically pursues when with the significant other (Fitzsimons & Bargh, 2003; Shah, 2003). In addition, there is evidence that one can unconsciously process task-irrelevant facial expressions (Preston & Stansfield, 2008) and be automatically vigilant toward negative or harmful stimuli (Öhman, Flykt, & Esteves, 2001; Okon-Singer, Tzelgov, & Henik, 2007) or toward undesirable tendencies such as stereotyping (Glaser, 2007).

Similar "unconsciously mediated" responses have been expressed toward stimuli that have been rendered imperceptible ("subliminal") through techniques such as backward masking, in which a stimulus (e.g., a word) is presented for a brief duration (e.g., 17 milliseconds) and is then followed by a pattern mask (e.g., #####). Under such conditions, subjects report that they were unable to perceive the word. It has been shown that subliminal stimuli can still influence motor responses, attention shifts, emotional responses, and semantic processes (Ansorge et al., 2007), at least to a certain extent. For example, in a choice response time task, response times for responses to subliminal (masked) stimuli are the same as those for responses to supraliminal stimuli (Taylor & McCloskey, 1990). In addition, subjects can select the correct motor response (one of two button presses) when confronted with subliminal stimuli, suggesting that "appropriate programs for two separate movements can be simultaneously held ready for use, and that either one can be executed when triggered by specific stimuli without subjective awareness" (Taylor & McCloskey, 1996, 62; see review in Hallett, 2007). Interestingly, it has been demonstrated that presenting subjects with "2 × 3" subliminally primes naming the number "6" (García-Orza et al., 2009). Moreover, some forms of Pavlovian, evaluative, and operant conditioning may occur unconsciously (Duckworth et al., 2002; Field, 2000; Olson & Fazio, 2001; Olsson & Phelps, 2004; Pessiglione et al., 2007). According to Strahan, Spencer, and Zanna (2002), certain action plans (e.g., eating popcorn) can be influenced by subliminal stimuli only when those plans are already motivated (e.g., when one is hungry). Subliminal stimuli can influence behavioral inclinations such as motivation and emotional states (e.g., as indexed by the skin conductance response; Olsson & Phelps, 2004; Pessiglione et al., 2008). Together, these findings reveal that subliminal stimuli can influence cognitive processing and behavior, at least to some extent.

The Unique Contribution of Conscious Processing or the "Phenomenal State"

According to the *integration consensus* (Morsella, 2005), consciousness furnishes the nervous system with a form of internal communication that integrates neural activities and information-processing structures that would otherwise be independent **(p.187)** (i.e., unintegrated). In virtue of conscious states, diverse kinds of information are gathered in some sort of global workspace (see reviews in Baars, 2002; Merker, 2007; Morsella, 2005). However, for some time it was unclear which kinds of information must be distributed and integrated in a conscious manner and which kinds can be distributed and integrated unconsciously: 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." Similarly, the ventriloquism effect involves unconscious interactions between vision and audition (Morsella, 2005). There are countless cases of unconscious intersensory interactions (see list in Morsella, 2005, Appendix A). These phenomena are consistent with the idea that consciousness is unnecessary, at least in some cases, 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 when holding one's breath). Specifically, SIT contrasts interactions that are consciously impenetrable with *conscious conflicts*, a dramatic class of interactions (e.g., one system vetoing the action tendencies of another system) between different information-processing systems. 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 multimodal) 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; Morsella, 2005). 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. These systems have been referred to as the *incentive response systems* (Morsella, 2005). Each system can influence action directly and unconsciously (as in the case of *unintegrated* action; Morsella & Bargh, 2011), but it is only through consciousness that they can influence action collectively, leading to *integrated action* (Morsella & Bargh, 2011). Integrated action occurs during a conscious conflict (e.g., when carrying a scorching hot plate or holding one's breath).

(p.188) Volition Is Most Intimately Related to One of Three Forms of Binding in the Brain

Thus, in the nervous system there are three distinct kinds of integration or "binding." *Perceptual binding* (or *afference binding*) is the binding of perceptual processes and representations. This occurs in intersensory binding, as in the McGurk effect, and in intrasensory, feature binding (e.g., the binding of shape to color; Zeki & Bartels, 1999). Another form of binding, linking perceptual processing to action/motor processing, is known as *efference binding* (Haggard et al., 2002). This kind of stimulus-response binding is what allows one to learn to press a button when presented with a cue in a laboratory paradigm. Research has shown that responding on the basis of efference binding can occur unconsciously. Again, Taylor and McCloskey (1990) demonstrated that, in a choice response time task, response times for responses to subliminal (masked) stimuli were the same as those for responses to supraliminal stimuli. In addition, in a series of studies involving subliminal stimuli, Taylor and McCloskey (1996) demonstrated that subjects could select the correct motor response (one of two button presses) when confronted with subliminal stimuli (see review in Hallett, 2007). The third kind of binding, *efference-efference binding*, occurs when two streams of efference binding are trying to influence skeletomotor action at the same time. This occurs in the incongruent conditions of interference paradigms, in which stimulus dimensions activate competing action plans. It also occurs when one holds one's breath, suppresses a prepotent response, or experiences another form of conscious conflict. In the SIT framework (Figure 10.1), it is the instantiation of conflicting efference-efference binding that requires consciousness. Consciousness is the "cross-talk" medium that allows such actional processes to influence action collectively. Absent consciousness, behavior can be influenced by only one of the efference streams, leading to unintegrated actions such as unconsciously inhaling while underwater or reflexively removing one's hand from a hot object.

Not requiring such cross-talk, unconscious perceptual processes (e.g., as in the attentional blink; Raymond, Shapiro, & Arnell, 1992) involve smaller networks of brain areas than phenomenal processes (Sergent & Dehaene, 2004), and automatic behaviors (e.g., reflexive pharyngeal swallowing) are believed to involve substantially fewer brain regions than their intentional counterparts (e.g., volitional swallowing; Kern et al., 2001; Ortinski & Meador, 2004). These finding are consistent with the tenets of both SIT and the more general integration consensus. Supporting SIT's notion that the suppression of a skeletomotor act requires conscious mediation, Brass and Haggard.(2007) present fMRI evidence that there is greater activation in a certain area of the frontomedian cortex when planned actions are canceled than when they are carried through.

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 override 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. Supramodular systems ("supramodular" because they are "beyond" the basic Fodorian module such as a feature detector) are inflexible in the sense that, without consciousness, they are **(p.189)**

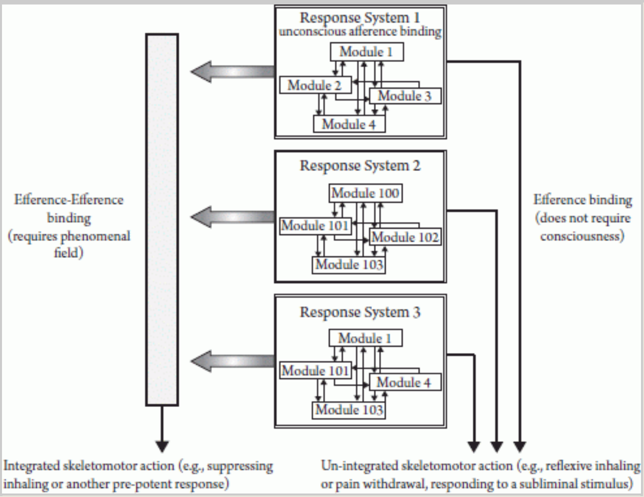

Figure 10.1 Fodorian modules operate within a few multimodal, supramodular response systems, each defined by its concern. Afference binding within systems can be unconscious. Although the response systems can influence action directly (illustrated by the arrows on the right), only in virtue of conscious states can they interact and influence action collectively, as when one holds one's breath (the path illustrated on the left). The sense of agency is most intimately associated to this efference-efference binding.

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 (e.g., create subjective avoidance tendencies) the onset of potential tissue damage even when the action engendering the damage is lifesaving. Regardless of the adaptiveness of one's plan (e.g., running across hot desert sand to reach water), the strife that is coupled with conflict cannot be turned off voluntarily (Morsella, 2005). Under conditions of conflict, inclinations can be *behaviorally suppressed* but not *mentally suppressed* (Bargh & Morsella, 2008). Although actional systems that are phylogenetically ancient may no longer influence behavior directly, they now influence the nature of consciousness: inclinations continue to be experienced consciously, even when they are not expressed behaviorally.

No Homunculus Is Required for "Volitional" Processing

Although phenomena such as alien hand syndrome (Bryon & Jedynak, 1972), anarchic hand syndrome (Marchetti & Della Sala, 1998), and utilization behavior syndrome (Lhermitte, 1983) have been explained as resulting from impaired supervisory processes (e.g., Shallice et al., 1989), SIT proposes that they are symptoms of a more basic condition —the lack of adequate cross-talk (i.e., interactions) among response systems. Without one system checking another, unintegrated actions arise, **(p.190)** wherein one system guides behavior and is uninfluenced by the concerns of another system. In this way, perhaps it is better to compare the phenomenal field not to a surveillance system but to a senate, in which representatives from different provinces are always in attendance, regardless of whether they should sit quietly or debate. In other words, phenomenal states allow for the channels of communication across systems to always be open (see discussion of *chronic engagement* in Morsella, 2005).

In phylogeny, the introduction of new structures (e.g., organs and tissues) involves complex, often competitive interactions with extant ones. This is known as the “struggle of parts” problem (cf. Mayr, 2001), and it may have been a formidable challenge during the evolution of something as complex as the human nervous system. Although such integration could conceivably occur without something like phenomenal states (as in an automaton or in an elegant “blackboard” neural network with all its modules nicely interconnected), such a solution was not selected in our evolutionary history. Instead, and for reasons that only the happenstance and tinkering process of evolution could explain (Gould, 1977; Simpson, 1949), it is proposed that these physical processes were selected to solve this large-scale, cross-talk problem. We will now discuss how the senses (or illusion) of volition and agency arise from these conscious states.

The *sense of agency* and *authorship processing* (i.e., attributing actions to oneself; Wegner, 2003) are based on several high-level processes, including the perception of a lawful correspondence between *action intentions* and *action outcomes* (Wegner, 2003). Research has revealed that experimentally manipulating the nature of this correspondence leads to systematic distortions in the sense of agency/authorship, such that subjects can be fooled into believing that they caused actions that were in fact caused by someone else (Wegner, 2002). Linser and Goschke.(2007) demonstrate that feelings of control are based on unconscious comparisons of actual action-effect sequences to the anticipated sequence: “matches” result in feelings of control, and mismatches result in the effect being attributed to an external source. Hence, when intentions and outcomes mismatch, as in action slips and spoonerisms, people are less likely to perceive actions as originating from the self (Wegner, 2002). Similar self-versus-other attributions are found in intrapsychic conflicts (Livnat & Pippenger, 2006), as captured by the “monkey on one’s back” metaphor that is often used to describe the tendencies associated with aspects of addiction.

Accordingly, in the classic Stroop task, participants perceive the activation of the undesired word-reading plans as less associated with the self when the plans conflict with intended action (e.g., in the incongruent condition) than when the same plans lead to no such interference (e.g., in the congruent condition; Riddle & Morsella, 2009). In two interference paradigms, response interference was associated with weakened perceptions of control and stronger perceptions of competition (Riddle & Morsella, 2009). It is important to appreciate that, despite these introspective judgments, and as revealed in recent action production research, there need be no homunculus in charge of suppressing one action in order to express another action, as concluded by Curtis and D’Esposito (2009): “No single area of the brain is specialized for inhibiting all unwanted actions” (72). For example, in the morning, action plan *A* may conflict with action plan *B*; and, in the evening, plan *C* may conflict with *D*, with there never being the same third party (a homunculus) observing **(p.191)** each conflict. *Ideomotor* approaches (Greenwald, 1970; Hommel, 2009; Hommel et al., 2001) have arrived at a similar conclusion: Lotze (1852) and James’s (1890) “acts of express fiat” referred not to a homunculus reining in action but rather to the actions of an incompatible idea (i.e., a competing action plan). From this standpoint, instead of a homunculus, there exists a forum in which representations vie for action control. In synthesis, it may not be that there is something akin to a self or supervisor overlooking action conflicts, but that the sense of agency emerges as a high-level cognition, a construction based on more basic processing, such as the conflict between actional systems.

Regarding the topic of voluntary action, one should consider that, more than any other effector system (e.g., smooth muscle), skeletal muscle is influenced by distinct (and often opposing) systems/regions of the brain. Figuratively speaking, the skeletal muscle system is a steering wheel that is controlled by many systems, each with its own agenda. Thus, *action selection* suffers from the "degrees of freedom" problem (Rosenbaum, 2002), in which there are countless ways in which to perform a given action. For instance, there are many ways to grab a cup of coffee: one could grab it with the left hand or the right hand, with a power grip or precision grip, or with three versus four fingers. This challenge of multiple possibilities in action selection is met not by unconscious motor algorithms (as in motor control; Rosenbaum, 2002) but by the ability of conscious states to constrain what the organism does by having the inclinations of multiple systems constrain skeletomotor output: whether by the conscious percept of a doorway, an inclination toward an incentive stimulus, or the urge to refrain from doing something impulsive in public, consciousness minimizes the degrees of freedom problem.

Conclusion

By following Sperry's (1952) recommendation and identifying the primary function of consciousness by taking the untraditional approach of working backward from overt voluntary action to the central processes involved (instead of working forward from perceptual processing toward central processes), one can appreciate that what consciousness is for is more "nuts-and-boltsy" than what has been proposed historically: at this stage of understanding, it seems that the primary function of consciousness is to instantiate a unique form of binding in the nervous system. This kind of integration (efference-efference binding) is intimately related to the skeletal muscle system, the sense of agency, and volition.

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Notes:

(1.) Often referred to as "subjective experience," "qualia," "sentience," "phenomenal states," and "awareness," basic consciousness has proven to be difficult to describe and analyze but easy to identify, for it constitutes the totality of our experience. Perhaps this basic form of consciousness has been best defined by Nagel (1974), who claimed that an organism has basic consciousness if there is *something it is like* to be that organism—something it is like, for example, to be human and experience pain, love, breathlessness, or yellow afterimages. Similarly, Block (1995) claimed, "The phenomenally conscious aspect of a state is what it is like to be in that state" (227).

(2.) In this task, participants name the colors in which stimulus words are written as quickly and as accurately as possible. When the word and color are incongruous (e.g., RED presented in blue), response interference leads to increased error rates, response times, and reported urges to make a mistake (Stroop, 1935; Morsella et al., 2009). When the color matches the word (e.g., RED presented in red), or is presented on a neutral stimulus (e.g., a series of X's as in "XXXX"), there is little or no interference.