

# Anticipatory consciousness, Libet's veto and a close-enough theory of free will

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Benjamin Libet concluded that, given the constraints caused by the timing of consciousness, all action is generated unconsciously. The power of consciousness, according to Libet, is in selection, in having the ability to veto each action before it is run to completion. In this paper we challenge the veto, by proposing that the role of consciousness exists prior rather than after the initiation of action. This is done through a modulation of the likelihood of automatic responses to constant stimuli. To account for the time lag of consciousness, we also suggest that conscious attention is focused on a predicted future in order to remain effectual to real time existence. Implications for free will are discussed.

**Keywords:** Free Will, Conscious Volition, Benjamin Libet, Time-Lag, Backwards Referral, Supervisory Attentional System

## Introduction

Benjamin Libet's experiments on the timing of conscious awareness have stimulated a long-standing debate regarding the existence and nature of conscious efficacy. His most heavily cited experiment (Libet 1985) aimed to determine where in the sequence of a voluntary action conscious awareness enters and acts. Libet demonstrated that awareness of an action (in this specific case, a wrist flick) occurs 250–350 msec after EEG-measured reaction potential technology indicates its onset or preparation. Libet logically concluded that since consciousness arises after the initiation of an action, it could not be causally involved in the action: "The initiation of the freely voluntary act appears to begin in the brain unconsciously, well before the person consciously knows he wants to act!" (Libet 1999: 51). If consciousness is acting at all, therefore, it must be doing so at least 350 msec before such voluntary acts occur.

Further experiments by Libet and others (for instance, Libet, Alberts, Wright & Feinstein 1967; Keller & Heckhausen 1990) have supported the concept of a conscious time-lag that would inhibit the ability of consciously-derived actions to respond in real time. Norretranders (1991) has argued, for example, that the time lag is a necessary consequence of the immense amount of stimulus information that must first be processed and then discarded to provide a coherent and concise story that we can consciously grasp. These conclusions appear logically sound. However, their implications still seem difficult to accept. If we cannot respond in real time with consciously determined actions, then our actions are necessarily unconsciously determined. Our perception of conscious self-efficacy – conscious free will – is illusory.

The hypothesis of free will as an illusion therefore appears to inexorably relegate consciousness to the realm of epiphenomenalism. Without any force of its own, consciousness is merely a parallel phenomenon that occurs alongside our actions – a spectator, not a participant. John Searle (2000) has suggested, however, that the epiphenomenalist explanation of consciousness is unsatisfying – in part because of its incompatibility with what we understand about evolutionary processes. First, consciousness is a complex and metabolically expensive biological process, as revealed by demonstration of the differences in the glucose consumption of unconscious and conscious brain states (Nofzinger, Mintun, Wiseman, Kupfer & Moore 1997). Second, the rapid increase in human brain size likely contributed to emergence of consciousness in humans. This encephalization process has resulted in significant evolutionary costs in the form of danger to both baby and mother during childbirth (Travathan 1987) and the prolongation of infantile dependence. The adaptive value of consciousness would therefore logically need to outweigh the costs that accompany it. But how much adaptive value could a system that is unable to make any changes to the actions of the organism have? As far as survival or reproduction is concerned, an epiphenomenal consciousness must be completely ineffectual. So why incur the costs? Either the epiphenomenalist argument is wrong, evolutionary theory is wrong, or something is missing entirely. Thus the problem remains unsolved and is a matter of heated debate.

Libet himself tried to fit the possibility of an active consciousness within his theory, by arguing that the purpose of consciousness was its ability to veto any unconsciously derived action. Various members of Libet's group (for example, Libet, Gleason, Wright & Pearl 1983) have shown that it takes 50 msec to deliver the synaptic message to move one's wrist. Conscious awareness of an action appears to emerge about 200 msec prior to the action. This means that only 150 msec remain for the subject to consciously choose whether or

not to proceed with the action. According to Libet's hypothesis, consciousness is a filter, capable of selecting which unconscious decisions result in action.

This veto argument, although influential, is not without its problems. Primarily: shouldn't this conscious choice, concerning veto, be unconsciously initiated as well? Libet (1999) tries valiantly to indicate that this is not necessary. However, he runs into the following problem: the veto choice is conscious and immediate, and must therefore occur in a window of 100 msec. Other decisions, as described previously, cannot be conscious because 300 msec are required for awareness of choice. In order to reconcile these seemingly incompatible ideas, he therefore constructs a complex logical case, describing the veto as "a control function, different from simply becoming aware of the wish to act" (p. 53). Finding no direct empirical support for this position, he is forced in the end to rely on a lack of counter-evidence: "And, there is no experimental evidence against the possibility that the control process may appear without development by prior unconscious processes" (p. 53).

Instead of a conscious intervention that affects the action outcome after it has been initiated, however, it appears possible that the active role of consciousness comes beforehand. In accordance with the Norman and Shallice (1986) theory of Supervisory Attention, we therefore propose that consciousness acts in an indirect and more temporally distal role, anticipating and perceiving upcoming stimuli (more than 400 ms into the future), and modulating the subject's largely unconscious preparatory responses. Norman and Shallice's model, our contributions to it, and a reinterpretation of Libet's veto will be subsequently examined in more detail.

### **The routinization of behaviour**

Shallice has provided an information-processing model of attention, based on a distinction between automatic and deliberate action that goes back at least as far as James (1890). In Shallice's view, automatic and deliberate actions are handled by two separate systems: the Contention Scheduling System and the Supervisory Attentional System. Routine, automatic, well-learned behaviours that do not require significant attentional resources are handled by the former system, while novel and non-routine behaviours are facilitated by the latter. The notion of Contention Scheduling is predicated on the assumption that complex motor programs (schemas, in Shallice's terminology) can be unconsciously initiated. This assumption is also shared by Libet, who holds

that all action is initiated without conscious involvement. Direct evidence for unconscious action initiation has come from many sources.

Australian physiologists Taylor and McCloskey (1990, 1996) have used backwards masking, for example, to elicit a complex and fully voluntary motor program, without triggering conscious attention of the eliciting stimulus. As the subjects of these experiments were not consciously aware of the stimulus that triggered their behaviour, so the argument proceeds, they could not have consciously initiated their actions. The validity of this argument is predicated on the assumption that the motor program elicited by the trigger must have existed prior to its initiation, as the processes underlying its construction are so complex that they could not occur (1) without conscious mediation and (2) in the interval between stimulation and action.

In a follow-up experiment (Taylor & McCloskey 1996), the researchers showed that subjects can manifest two pre-programmed (previously learned) voluntary motor responses to two different masked stimuli. Taylor & McCloskey have not yet established an upper limit to the number of pre-programmed response patterns that might be held in readiness, nor determined how complex these programs can be. However, the authors do suggest a primarily unconscious and pre-programmed interaction with the world, in a manner that would allow for Libet's time-lag of consciousness,

Almost all motor reactions and many other motor performances must occur before conscious perception of their triggering stimulus. Such a model could allow the stimulus to act as a trigger when only a small amount of sensory data has been processed, although conscious perception would require further sensory input. (Taylor & McCloskey 1990: 445)

Recently, Ann Graybiel (1998) has suggested that many motor actions may be grouped – or chunked – together to form structures similar to the Miller's (1957) compression of discrete bits of information in memory) recodes mental representations of action sequences by reducing the number of distinctively represented units – essentially collapsing several motor programs into one. Thus, these action repertoires, once elicited, run both automatically and ballistically. In Shallice's contention scheduling, an action schema competes with others and, when exceeding a threshold, is activated. To avoid conflicting action patterns, activated schemas laterally inhibit the related and competing ones (see Cooper, Shallice, & Farrington 1995 for a discussion and simulation of the contention scheduling system). Recent work reviewed by Swanson (2000) lays a plausible hierarchically-structured neurophysiological platform underneath these speculations: some sensory input is relayed directly to hypotha-

lamic and lower spinal motor control systems, operating very rapidly but at an “unconscious” level. Another sensory branch relays incoming information up into cortical areas concerned primarily with complex but time-consuming high-resolution perception.

However, in non-routine or novel situations, in situations where deliberate attention is required, or when existing schema become error prone, another mechanism is necessary. The Supervisory Attentional System (Norman & Shallice 1986) does not directly select actions, but applies extra activation or inhibition to the Contention Scheduling system in order to *bias* the selection of particular schemas. Thus, attention directed towards a certain plan of action greatly increases the likelihood of that plan being selected by Contention Scheduling. For example, while at bat in baseball, one’s attentional resources are directed towards hitting the oncoming pitch, rather than, say, catching it. The simple conscious concentration on this goal biases the selection of the “hit the ball” schema which itself is a hierarchy of efferent muscle commands controlling the aim, step and swing. In the case of schema malfunction, when one of the automatic sequences is identified as faulty, it cannot be fixed in real time, partly for reasons of time constraint, and partly because the individual components of the sequence have been chunked into a whole and are no longer available to voluntary regulation at the level of detail required. The program must therefore be brought into attention and unpacked into its constituent parts for it to be repaired. The processes underlying playing a musical instrument, such as a guitar, provide a relevant example. Individual muscle movements are chunked into the fingering and plucking or strumming of strings. These notes and chords are themselves chunked into progressions. The underlying motor “macros” operate ballistically, increasingly, as expertise with the musical piece is developed. Once a bad habit is established, the attempt to modify it requires the unpacking, or unchunking, of that part of the hierarchy that is now underneath a conscious level. What this means, in essence, is that “consciousness” moves up a motor hierarchy, as each level of that hierarchy becomes automated. Once automated, however, the level is “unconscious,” and has to be unpacked before it can be repaired or changed.

### **Indirect conscious control through the biasing of attentional resources**

There is strong clinical evidence that the conscious willing of action and the actual execution of the actions are handled separately within the brain, stemming primarily from analysis of “double dissociation” disorders – where one process

is damaged but not the other (see Appendix). Some of this clinical evidence suggests that automatic behavioural macros extend beyond motor sequences, into the domain of “object” perception – something very much predicated on use, rather than material or objective feature (Gibson 1979). Indeed, Shallice and his colleagues (Cooper, Shallice, & Farrington 1995), describe the process of “environmental activation.” Though the presence of a single object or “stimulus” can initiate a specific schema, they explain, it is more likely that complex and sophisticated schemas will be activated by more complex, evocative environmental situations such as combinations or arrays of objects (for example, a lit match and a dangling cigarette) (see Jeannerod 1997 for a similar discussion).

However, the idea that such automated perception-motor spanning processes exist can also be integrated productively with the idea of the Supervisory Attentional System. It has been clearly demonstrated that selective attention can alter the way visual stimuli are perceived, from the simple and meticulously studied reversibility of the Necker cube (Orbach, Ehrlich, & Haith 1963) to the complex ability to discriminate “objects” from the surrounding sensory clutter. Consider the well-known cocktail party effect (Cherry 1953) or, more recently, the results of fMRI studies conducted on the nature of visual attention by Kastner, De Weerd, Desimone, & Ungerleider (1998). These researchers discovered that mental representations of various stimuli in a cluttered array interact in competitive and mutually inhibitory ways. Each stimulus expresses a suppressive effect on other neighbouring stimuli in the visual field. However, focusing attention on one particular stimulus offsets the competing suppressive effects induced by these neighbouring stimuli. This mechanism of selective attention is loosely analogous to the lateral inhibition involved in Shallice’s contention scheduling. (Cooper, Shallice, & Farrington 1995). Thus, the Supervisory Attentional System may also be directed at the sensory field, biasing certain perceptions, rather than their associated motor responses.

One might notice a similarity between the properties that serve as action cues and the concept of affordances characteristic of J. J. Gibson’s theory of direct perception (Gibson 1979). According to Gibson, an affordance is what an object in the environment offers an organism, what it invites from the perceiver – a chair, for instance, would have the affordance of sitting, a glass of water for drinking, air for walking through, etc. The three fundamental properties of Gibsonian affordances are

1. An affordance exists relative to the action capabilities of a particular actor.

2. The existence of an affordance is independent of the actor's ability to perceive it.
3. An affordance does not change as the needs and goals of the actor change.

Though affordances are a useful way of thinking about the action cues offered by objects, Gibson's definition appears too limited – particularly with regards to his final two points. In keeping with his over-arching theory of the directness of visual perception, he maintains that affordances are invariant properties of an “object.” However, the direct perception hypothesis, which centred around an absence of any perceptual processing, has never gathered mainstream support (see Fodor, & Pylyshyn 1981 for an early criticism). By looking at affordances as a property of the shared interaction between subject and object, and considering that the subject's perception of the object *does* affect its affordance, it becomes clear that the affordance of an object can change not only relative to the action capabilities of a particular subject as Gibson suggests, but between subjects with the same capabilities, and, importantly, *within* the same subject. There is no reason why a knife could not reveal the affordance of either cutting bread or spreading butter, depending on the current goals and attentional focus of a subject. Therefore, it is one's attention that alters the perceptual interpretation of information; for all intents and purposes, the same sensory information is seen as a different object, with different affordances and, as a result, different action responses. Indeed, what is seen as an “object” may be better understood as patterns of environmental information that, over time, have distinguished themselves from the background as possessing utility. The potential utility of the object evokes attention, because of its associated with incentive reward (a consequence of the apprehension of the potential).

Even in the absence of direct sensory information, “objects” and their affordances can be reinterpreted by directing attention to the standing mental representations held in memory. Identified objects or situational patterns, previously understood in a particular context with an associated action, can be mentally reexamined for further implications for behaviour. Coming to interpret things differently allows one to remap their significance and change the motor actions associated with them for future encounters. This can be done rapidly, but not instantaneously (ie under 350 msec), as it does require conscious attention, and conscious attention, as we have discussed, takes time.

We have thus far suggested that conscious volitional control operates indirectly through modulation of the attentional mental environment. In effect, the current state of conscious intention biases certain perceptual interpre-

tations of external information. There are motor habits associated with any given perceptual interpretation, that actually constitute part of that interpretation. Once something is seen in a particular way, therefore, the probability that certain patterns of action will be implemented is increased, as a matter of course. The phenomenon of utilization behaviour (Lhermitte et al. 1986), described in the appendix, provides the clearest evidence for this method of perceptual response. Prefrontally damaged individuals characterized by utilization behaviour react “automatically” with action to the presence of objects, and cannot inhibit that automatic response. The prefrontal cortex, whose inhibitory capacity is well-documented (Fuster 1993) determines which of these perceptual-motor programs are relevant and appropriate and disinhibits them, allowing them to “pass through the gate.” Once the decision has been made, all other perceptual possibilities and competing affordances are laterally inhibited further in order to avoid conflicts.

Though our capacity to directly and consciously determine which motor programs are activated may be severely limited, the same cannot be said of our ability to affect action. For example, a glass of water, under circumstances where one was thirsty, would elicit a liquid container perceptual scheme and a drinking motor program. However, were there a fire, the affordance interpretation of a glass of water would be one of a “fire extinguisher” thus activating a very different motor program. Alternatively, if a nearby staple needed to be flattened or a stack of windblown papers subdued, the perceptual scheme activated by the pattern that constitutes the glass could easily be “manipulable solid heavy surface near at hand” and the affordance interpretation “hammer” or “paperweight”, respectively. In this manner, the attentional environment, under the modulation of a goal-directed consciousness, is the determinant of how objects are perceived, and which motor programs are likely to be initiated. The conscious subject need only be aware of her goal to align her automatic actions with it.<sup>1</sup> Is this free will? If by will, one means the ability to will certain perceptions and actions into a high probability of occurring, then yes. If, however, one is referring to deliberate, direct control of those perceptions and actions, then the answer is no. However, this ability seems close enough to free will to qualify. As conscious beings, we do not force our own hands. Instead, we whisper suggestions, by modulating our intention and perception. This ability could be seen as one of the primary functions of consciousness – the ability to interact with the same world and situation in multiple ways via the plethora of perceptual and action programs afforded by the flexibility of attention.

One problem remains: Given the delay of consciousness, the time lag necessary for processing, how can it affect real-time activity? Shouldn't the



attentional environment always be delayed? Shouldn't this bias the organism towards anachronistic reactions?

A speculative solution to this problem is presented in the next section.

### **Conscious attention, detached from and unable to control real-time responses, focuses on events that will occur within a time frame to which it can react**

In order for us to consciously modulate our future responses, we need to be able to anticipate that future. Since there is a relatively long delay in the elicitation of conscious sensation, and still more time required for consciousness to modulate any upcoming response, the attention of consciousness must be directed far enough in the future for it to be effective. This necessity is clearly shown in a variety of real-life situations. For example, when skiing, our attention is not directed to the space immediately in front of our boots. It is too late for us to consciously affect any outcome relevant to that space. Depending on our speed, therefore, we pay attention to the terrain a few meters ahead of us because we are much more able to consciously modulate how we will perceive and respond to that terrain when we reach it. We learn to take into account how long is required for our conscious responses. At time frames smaller than this gap, our responses are already fixed and we are impotent to change them; the unconscious responses run automatically. We thus have the capacity for free will, but not over short durations. For this reason, our conscious attention is most frequently fixed on the future.<sup>2</sup>

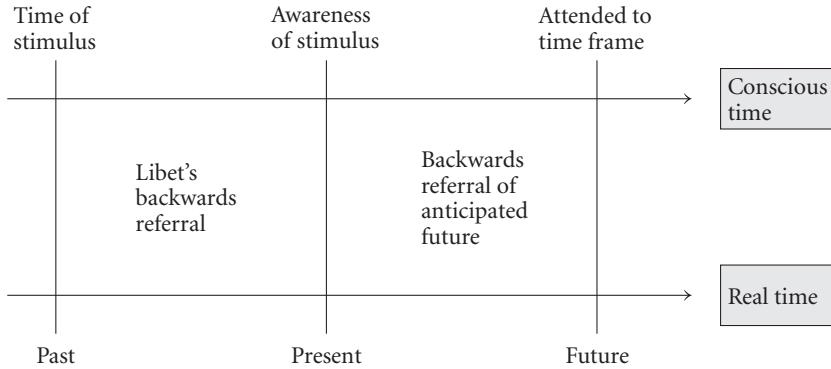
This attentional fixedness on the future is evident in eye-tracking studies that examine, for example, the gaze of piano players on their musical notation. According to the tenets of the theory offered here, skilled pianists consciously observe the musical notation before them to prime and then elicit previously automatized, complex repertoires of finger movements. After a given action repertoire has been initiated, however, any changes to that particular "macro" would be impossible to implement. Thus, attending to information within the temporal span of that macro would be useless. We would expect that pianists would attend to the bars of music suitable for priming the *next* action macro. Indeed, skilled pianists look between two and five fixations (the length of a "look") ahead (Gilman & Underwood 2003; Truit, Clifton, Pollastek & Rayner 1997; Rayner & Pollastek 1997; Goolsby 1994). Furthermore, experienced musicians look farther ahead than inexperienced ones. This is precisely what we would expect, given that more experienced players likely develop larger-scale

macros. Similar behaviours, including the skill difference, characterize touch-typists (Inhoff & Wang 1992; Salthouse 1984)

Beyond the recognition that consciousness simply attends to the future, we propose that our subjective experience construes this future as the present, at least for short-duration decisions. In other words, the anticipated near-future is referred backwards and interpreted as the present. Nijhawan, (1994) demonstrated, for example, that experimental subjects can be induced to misperceive a set of moving dots as further ahead of a set of flashing but stationary dots when the two sets were actually aligned. Subjects typically perceive the moving dots on a trajectory line 100 msec ahead of where they actually are. Thus their perception of the present actually reflects their prediction of the near future. Known as the flash-lag effect, this phenomenon has been demonstrated by Nijhawan and his colleagues in a variety of permutations of the original experiment (eg, Khurana, Watanabe, & Nijhawan 2003). The phenomenal experience of moving objects is an extrapolation of where the object will be.

Such results make sense, when considered as anticipatory preparation for action. To account for the time it takes to become aware of useful information and to modulate an appropriate reaction, it is necessary to focus attention on the future. By perceiving the immediate future as the present, we can actually believe that consciousness is acting in real time on the (misconstrued) present, when it is actually preparing for the (likely) future (see Figure A). This is consistent with Libet's backward referral, which maintains that the present is interpreted as the past. Libet showed that a skin prick is only consciously experienced 500 msec later, but then referred back in time to when it actually occurred, so that it seems like the sensation was consciously experienced just (20 msec) after the skin was actually pricked. Thus, in order for consciousness to seem efficacious, despite its time-lag, the entire subjective interpretation of time is shifted ahead of the actual time.

This is not something either rare or strange. Klein (1999) and Hameroff (1999) explain, for example, that such mental juggling of temporal states occurs often, and is quite necessary for coordinating sensory information that arrives at different times from different parts of the body. The brain is actually quite capable of reorganizing information to create a smooth and consistent experience. Because of our capacity to time shift, it is perfectly possible for us to perceive the predicted future as the present. Because we can predict reasonably accurately, this shift generally causes us no trouble, and simplifies our interactions with the world. However, the cost of the gap between prediction and actuality is vulnerability to error. When the actual present does not match the immediately predicted "future," we place ourselves at risk. Our accu-



**Figure A.** The conceptual relation between Libet's Backwards Referral and Anticipatory Consciousness

racy is compromised during situations that are very rapidly and unpredictably changing. Since our conscious attention is directed towards a future that hasn't happened yet, it can only make predictions to the best of its ability. This is why not all reactions are perfectly accurate. The ballistic motor program selected is done with dated information spuriously presented as up-to-date.

### Implications for Libet's veto

In this paper, we have borrowed from, expanded upon and questioned parts of Libet's original theory of conscious action and free will. We have outlined mechanisms that allow, hypothetically, for the existence of constrained free will and the experimental results that would call free will into question. We have, however, taken issue with Libet's veto clause, believing that the capacity for veto is neither necessary for the existence of free will, nor a manifestation of that will in the manner Libet proposed. Instead, we suggest that the genuine vetoing of a command is achieved only by a competing and overriding schema activated by contention schedule (Cooper, Shallice, & Farrington 1995). Such a schema would have enough activation strength to displace whatever schema was currently being run. More reflexive perceptual schemas and motor reflexes, such as those characterizing startle and freezing, for example, are the most likely to be strong enough to overcome previously run macros. The neurocircuitry that mediates such responses is certainly characterized by the structure that would enable such displacement (Swanson 2000).

Alternatively, our indirect conscious control inhibition of a response. In Libet's experiment, such bias would characterize the wrist flick. However, given the time frame of such shifts of conscious attention, the biasing would have to occur prior to the initiation of the action, not within the final 100 msec. Having biased the activation of the inhibitory schema, it would compete with and successfully thwart the wrist flick schema using the contention scheduling process described above. This, however, would not be a veto in the way that Libet described, since consciousness offered its input before, rather than after, the initiation of the action. To better understand this process, you might raise your fist and slam it back down on the table. Do it a second time, but this time, just before it strikes the surface, stop it from happening and hold your fist an inch above the table. The conscious inhibition did not occur during the downward action. It couldn't. There wasn't time. Instead, the inhibition came prior to the action. The almost-strike-the-table-schema was biased over the strike-the-table-schema. Notice that, this time, you didn't wince.

## Conclusion

The easy and hard problems of consciousness are enormously challenging and will, no doubt, continue to be so for some time. In addressing the question of conscious volition, we have faced just one of these challenges. The theory we offer provides a plausible and coherent solution to some of the problems that have arisen in the debates regarding the existence and nature of conscious free will.

The concept of anticipatory consciousness, wherein our conscious perception of the world is shifted forward to take into account the processing time-lag, introduces a way that a time-intensive consciousness can remain effective in a world that often progresses faster than the speed of thought. Meanwhile, we believe that the two major aspects of consciousness – its phenomenology and volition – are functionally united by postulating phenomenological awareness as the key ingredient in conscious choice. The voluntary direction of attention allows us to consciously bias the selection of a host of ballistic automatic action patterns. Though some actions are not under direct conscious control, the conscious input we do have allows for a working theory of some sort of free will, or at least something close enough.

## Appendix: The clinical neuroanatomy of volitional and automatic action

The separation of the willing, initiation and execution of motor action has been well established, mostly from clinical disorders, but also from directed animal studies and human neuroimaging. Researchers have attempted to compile this evidence into an anatomical model of the processes involved in such actions. It should be noted, however, that making definitive causal claims about specific structures is difficult and often contested. We will begin by examining some disorders of the basal ganglia.

Those suffering from Parkinson's disease, characterized primarily by a loss of dopaminergic neurons in the substantia nigra pars reticulata (SNr), find themselves unable to perform the actions patterns they intend to. As Spence and Frith (1999) indicate, such patients often freeze up altogether, knowing "precisely what action he wants to perform, but unable to initiate it" (p. 20). Similarly Huntington's disease, caused by atrophy of the striatum, results in both unwanted movements as well as impairment in the acquisition of new motor skills (Hiendel, Butters & Salmon 1988) Both Huntington's and Parkinson's disease involve damage to different parts of the basal ganglia, which have been implicated as the key structures involved in the execution, but not conscious selection, of action schemas (Spence & Frith 1999). Hikosaka and colleagues (Hikosaka, Miyashita, Miyachi, Sakai & Lu 1998) have tried to test this supposition experimentally by using a GABA agonist to create reversible lesions in parts of monkey brains in order to observe the differential effects on the learning and performance of visuomotor sequences. They found that the pre-supplementary motor area (pre-SMA) and the caudate in the basal ganglia are likely involved in learning new sequences while the putamen and the cerebellar dentate nucleus are involved either in the storage or retrieval of these sequences. The differential roles of the caudate and putamen help explain why Huntington's disease, a disorder of the entire striatum, affects both motor acquisition and performance.

Human functional neuroimaging in the same study confirmed the role of the pre-SMA in learning, and added the dorsolateral prefrontal cortex (DLPFC). As a sequence became more learned and routinized, activation moved posterior to parietal regions. They concluded that the prefrontal cortex, the pre-SMA and anterior regions of the basal ganglia initiate the learning of sequence which, once learned and automatic involve the posterior basal ganglia, parts of the cerebellum and parietal lobe. Matsumoto and colleagues (Matsumoto, Hanakawa, Maki, Graybiel, & Kimurai 1999) followed up on this research, but expanded the role of the striatum to both the acquisition

and retrieval of learned motor programs. They implicated the nigrostriatal dopamine system as central to the entire process of learning, storing and retrieving procedural memory.

Frank, Loughery and O'Reilly (2001) build on this cursory model of action selection with reference to the "gating" nature of the basal ganglia. The projections within the basal ganglia, from the striatum to the globus pallidus internal segment (GPi) or substantia nigra pars reticulata (SNr) are inhibitory as are those from the GPi/SNr to the thalamus. In the latter case, it is the constant firing of the GPi/SNr neurons that serves to inhibit the thalamic neurons. Thus, when the striatal neurons fire, they inhibit the constantly firing GPi/SNr neurons which, in turn, disinhibits the thalamus (Chevalier & Deniau 1990). Thus, the firing of the striatum has been referred to as "releasing the brakes" for motor actions. The actions are selected by cortical regions which project to the striatum which, in conjunction with the rest of the basal ganglia, "releases" the motor plan associated with it. Consequently, the thalamus projects to the motor cortex and the plan is run.

Spence and Frith (1999) break down the system into three parts. The DLPFC, in conjunction with the anterior cingulate cortex, is involved in the selection and creation action patterns. Both regions were shown to be differentially activated when subjects were asked to pay attention to their actions (Passingham 1997). Ingvar and Philipson (1977) have noted similar activation when subjects were told to simply imagine making movements. Incidentally, Shallice (1988) places his Supervisory Attentional System squarely in the frontal lobes. The prefrontal system was contrasted with the subcortical system comprising the basal ganglia and the cerebellum which were more involved in the execution than the selection of action. Finally, the parietal cortex is responsible for the storage of the motor programs.

These results are consistent with the distinction between action intention and action execution. Just as those with Parkinson's disease suffer an inability in action execution, but an intact ability action intention, one would expect to see the opposite pattern in those with frontal damage, but intact basal ganglia. Though the frontal regions are much more complex, this expectation is confirmed by the clinical evidence from at least two frontal lobe disorders. Graybiel (1998) describes obsessive-compulsive disorder patients who are compelled to perform action sequences without their explicit intention. Patients suffering from Utilization Behaviour (Lhermitte, Pillon & Serdaru 1986) have an overreliance on environmental stimuli for action. For example, they would automatically drink from a glass of water placed in front of them, or attempt to use a toilet every time they walked by. Upon exposure to the relevant cues,

these patients cannot help from performing the associated motor plan, even when entirely inappropriate. Lhermitte described the process as a loss of intellectual control manifested by impairment of frontal lobe inhibition, resulting ultimately in unrestricted release of parietal lobe activities. Norman and Shallice (1986) suggested that this disorder represents a dysfunctional Supervisory Attentional System (For a more exhaustive account of relevant evidence, refer to Norman and Shallice 1986 or Shallice 1988).

## Notes

1. Many terms have been used to describe the collection of motor responses, including behavioural macros (Graybiel 1998), scripts (Schank & Abelson 1977), memory organization packets (MOPs) (Shank 1982) and schemas (Norman & Shallice 1986). These terms can be considered largely synonymous.
2. A series of experiments by John Bargh and his colleagues (Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trotschel 2001; Chartrand & Bargh 1996) have revealed that even the goal behind a pattern of activity may remain outside of conscious awareness. Subjects were unconsciously primed with certain words that affected their goals and consequent strategies in an ambiguous situation. These results raise an important note: Consciousness is a sufficient but not *necessary* condition for the occurrence of the attentional biasing. One could just as easily allow attention to be drawn to things automatically, as a result of the current motivation. However, volitional power comes from the ability to purposefully direct this attention, from, for example typing on a computer screen to the paper on my left to the paper's affordance to be picked up and read.
3. This conscious biasing can be done more distally and broadly in order to prime certain fast reactions later. This might help explain why mental visualization improves performance in skilled activities. By running a mental "simulation" of a certain activity, attention is primed to be directed at the perceptual-motor macros, hastening their unconscious elicitation and improving accuracy.

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