

Human Consciousness: A Revised View of Awareness and Attention

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As noted in earlier work (Lonky, 2003), the continuity of consciousness is a reality, provided by the blending of the combination of both conscious aware states with conscious, but unaware ones, and where the frequencies governing the interleaving of the two states prevent us from ever directly deciphering the nature of their discrete properties. As a consequence, we cannot experience any discontinuity within the global phases of consciousness itself. The impact of this continuous cycling has major implications towards the purpose and mechanics of the aware cycle within the conscious process, as well as the role of attention. A model is presented wherein these cycles are mirrored in ocular motion, and both are related to autonomic mechanisms. Concepts are presented that argue for the aware state function to be largely centered on the management of attention, while providing feedback to the unaware cycle. The empirical concept developed is then tested against both current experimental data and several longstanding consciousness processing conundrums, with favorable results.

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It is hard to imagine that as humans, when we “think” great thoughts or combine new experiences with old memories, that we are not “directly” aware of the recall process itself. But that appears to be the correct description of what has yet to be the unfurling of the most challenging science project of the new century, understanding and controlling consciousness (Schacter, 1996). It is clear, however, that when we are asked for an address or a phone number, we recite it within hundreds of milliseconds, which appears in the normal course of events as fairly instantaneous. However, we do not “recall” the process of remembering it, nor do we specifically recall how we got to that data (i.e., what other data choices we eliminated to get to the ones we uttered). In fact, until the words came out of our inner thoughts,

or out of our verbalizations, we were not “aware” of what we would say until we heard it *from ourselves*. That does not mean that we were not conscious of our knowledge, or our ability to come up with the right answer (Bischoff-Grethe, Proper, Mao, Daniels, and Berns, 2000; Sharaie, Weiskrantz, Barbur, Simmons, Williams, and Brammer, 1997), but rather emphasizes the experiential fact that we are unaware of our thoughts until they are either silently or verbally expressed within our awareness (Merikle, Smilek, and Eastwood, 2001). That same proscription of knowing holds true for the application of all of our skills in mathematics, despite the level of our previous learning. After we pose the problem, say 11 times 5, we are only aware of the answer, 55, but not the notion of how we arrived at it. For example, did we just replay a previously recorded value, or did we remember “how to multiply by 5s or 11s”? None of this information is recallable, as we are privy only to answers. Thus, the pre-processing of thoughts, the selection of the next right verbal words for ongoing sentence construction, the sorting of feelings and expressions prior to speaking (either silently or out-loud) are all accomplished in the “conscious, but unaware cycle” of the total human conscious process.

The same concepts ring true in the areas of motor activation, when we walk without awareness of a stepping cadence, or drive a car without full awareness of the street details passing by. Some neuroscientists label this peripheral focus or absolute focus as part of a variable called “attention,” but we would need to distinguish carefully between what is in our purview to “attend to” and what is not. The portion of consciousness that is forever in the unaware cycle cannot be the focus of conscious attention, because it will not yield to any level of concentration. Attention, as such, is a tool we use within the aware cycle to bring focus to one or one set of facts or events preferentially over another. By excluding others, or relegating them to subordinate roles, we are setting up the pieces that count in the complex thoughts that humans exhibit. Part of this facet of continuous consciousness contains what psychologists refer to as the subconscious. That term can be misleading though, because there is a suggestion that you can remember something or address something directly that is “just below the surface of awareness.” This would only be true if one were to have contact with those intimate details and the mechanics of unaware thought — apparently not obtainable, since those mechanisms of the unaware processes are not subject to direct recall. As conscious awareness is but a fraction of the rapidly repeating and interleaved conscious cycles alternating between aware and unaware, and details of these unaware dynamics are not available within awareness, then the concept of a classical “subconscious” might have little meaning within this description. During the two phases of consciousness, aware and unaware (which is the sum total of all our conscious experience), we become con-

scious of *everything* around us that our sensory capabilities may have been stimulated with (Merikle and Daneman, 1998). We are only cognizant during the aware cycle, and thus have limited verbal reporting ability concerning the whole scene or *everything* we have sensed. It would then appear as if our brain “filled in missing details,” but that would not be the case. Rather, we always “knew” what was in the scene, but were not “aware” of all of it in the part of the process we verbally report on, which is conscious awareness. Indeed, if we filled all the data in with our brain as a “construct,” the resulting image in our mind would not necessarily comport as closely with actual photographs of the scene or the physical data; it would only be very rough approximations of them. Since we are indeed conscious of all the experiential content within this bimodal cycle, consciousness will appear continuous, despite only reporting on part of it during awareness.

Awareness allows us to “experience” what we say or think or do, and to provide those sensations and thoughts as input to the next series of conscious, but unaware time windows, perpetually updating thought and improving knowledge through never ending volleys of aware cycle feedbacks. In that manner, we provide steering of the main conscious process through a real-time, on-the-fly feedback. Often, we may feel or express “that doesn’t sound right,” or “that feels wrong,” and make corrective action happen in real time (Mangan, 2001). Not so obviously, we take those feelings that we develop during the aware cycle (and appear only peripherally attuned to), and use them in real-time as well to alter the subsequent words and concepts that will have been chosen during the next unaware cycle (Merikle and Joordens, 1997). The conundrum is that the core activities involving choice are being done essentially in the unaware mode. The proposition that we cannot directly (on an instantaneous basis) affect the nature of our outputs (from memory or experience) that emanate from this unaware portion of the consciousness cycle is new, but not unfounded. Logothetis and Schall (1989) have shown that information learned in unaware states can have an effect on those representations we feel during our aware periods. While making decisions in an unaware mode does appear to be a conundrum, it nonetheless also comports with our own personal understanding of how we seem to come up with thoughts, plans and feelings about our interactions with the external environment, and with other people. It is also supplemented in this model with the fact that we can consciously (through an aware feedback cycle) modify the unaware content afterward (both thoughts and feelings). This concept actually makes Chalmer’s (1996) “hard problem” potentially less hard, in that perhaps we don’t really store all of our subjective feelings with recorded facts, but generate many of them in real-time. The hard problem has at its core the dilemma of where the neural correlates of subjective feelings reside. Perhaps instead of actual resident storage we instantaneously feel

grief when in the company of mourners. That process would happen so quickly during the cycling of aware to unaware, that it would appear to be true content that came simultaneously with the data, and there would be no "explicit" or permanent neural correlate. The concept that consciousness (as we instantaneously experience and feel it) is the current content of awareness, as enriched by the catalog of permanent storage held in the brain for retrieval and updating in unawareness, can provide a framework for understanding many of the details of experimental neuroscience and psychology.

The fact that such a fundamental rhythm between two operational phases of total consciousness exists, is rational based on experience, but nonetheless difficult to explicitly measure because of the intrinsic nature of the two periods, aware and unaware. Although consciousness appears seamless, there have been implicit measurements reported in experimental neurology and psychology that point to cerebral processing happening within discrete time intervals. The smallest quanta of time in the realm of sensory perception appear to center on time intervals of 50 msec to 80 msec within the areas of touch, sound and vision. In the somatosensory area, the strongest evidence for these parsed intervals comes from backward masking experiments, where a strong sensory input can nullify a weaker one, delivered up to 80 msec earlier (MacIntyre and McComas, 1996). Other strong evidence within the sensory domain is the inability to distinguish the order of separate stimulus presentations within short times of each other (Hirsch and Sherrick, 1961). Standing sound waves generated within the brain using binaural beat frequencies also appear to be optimal from 10 Hz to 20 Hz, the latter corresponding to beta waves of 50 msec duration (Oster, 1973). Of course, visual flicker fusion is also suggestive of parsed quanta of time, where information or content is stored in consciousness before change is sensed. This paper will address the visual system more directly in a later section, but the reality that total conscious perception or attention is rhythmic, and that models of consciousness must include neural processes that account for un-disturbed information periodically changing about every 80 msec, is very clear. The proposal advanced in this theory is that these intervals are provided for by the rhythmic switching between the aware and unaware states of consciousness.

Besides this feedback phenomena that permits existing memories and experiences to be "updated or overridden" by present thoughts or observations, the aware cycle provides the arena for compounding and co-mingling the existing data (memories) extracted during previous unaware portions of the cycle with these newer or current observations and feelings. For lack of a better description, this would be the basis for compound thinking, decision making, generation of new facts, and new experiences. The combined (and semi-rapid) blending of the unaware and aware content is the experience of

consciousness each one of us has, and is as unique for each of us as we are from one another. Without the presence of a formidable aware cycle, we would be confined to the world of our earlier predecessors, where conscious content would be ruled by instinct, emotion, and sensory experience (Carruthers, 1998). Clearly some lower forms of mammals function that way. The evolutionary leap made by humankind was to instill a highly developed aware cycle within the periodicity of consciousness. Coupled with a prefrontal cortex that exhibits extensive neuronal connectivity which has the ability to fire over extended periods of time and maintain stimuli (Fuster, 1977; Wood and Grafman, 2003), the combination of this rhythmic model of consciousness and the “sample and hold” capability of the prefrontal cortex allows for “human” thinking, which is by far the most complex on the Darwinian scale.

As noted earlier, attention itself is an intended sensory focus on some portion of the data/emotion content of the current aware cycle (Lamme, 2003). For an individual to “attend” to one specific fact, happening or emotion, or a set of the same occurring over many aware cycles to the exclusion of the rest of the scene would, in essence, be the equivalent of placing a blockade, or filter over the totality of the content being recalled during the unaware cycle, and only passing through the germane features matching those “attended” items. The analogy that best fits this picture is when we place a color filter in front of a camera used to take a photo in daylight, we selectively enhance the specific color items within the scene, and remove or diminish others. Attention, as a process, is potentially cued in as a sensory response that rapidly overwhelms the ever present “silent thought” data stream, and can subsequently be enriched by the ongoing cycles of the unaware mode. It is as if this bimodal system of consciousness *must focus on something, and provide feedback* during our waking moments.¹

The cycle of recalling data from the unaware, but conscious period, then providing new feedback to the next unaware period repeatedly, modifying thought content cycle by cycle, sounds like (and may well be) an autonomic process. We can also extend this basic presumption and assume that the aware feedback content may ultimately slow down as cerebral processing is “memory” limited (there is just so much workspace for the data within any given physical period, and a break may be needed for the “emptying” of the cache). Without such emptying perhaps, no further feedback processing could be possible. In the case of the conscious physical process already described, stopping the feedback can only occur regularly by shutting down

¹Attention deficit may actually be a misnomer, in that attention cues may not be missing or inadequate, but rather too plentiful, with not one of them dominant over the other.

the conscious aware cycle, and that means going to sleep. If this hypothesis is valid, then the converse may also be true: sleep is required by the conscious process regularly to “empty” the associated workspace. As long as we are “attending” to anything during our waking time, we are providing feedback to our processing brain and loading the working memory automatically, so sleep’s necessity is automatic as well.²

The shutoff switch for awareness (the portion of consciousness we are ultimately familiar with) is “sleep.” To provide for the “rest or refresh” processes described earlier, the so-called “sleep/wake” switch would be responsible for the “shutoff” and “turn-on” of the conscious aware engine, and hence, consciousness as we know it. The sleep/wake switch’s role in both the sleep process and in the brain/mind activation could be similar, if not identical. This is a critical part of the bimodal aware/unaware consciousness theory presented here, where the aware state, which provides steering and feedback to the choices or data we recall from the unaware state, can have its processes temporarily suspended by falling asleep. Even though we know our brains are active during sleep (and in REM, very active), the portion of consciousness that we operate with would be suspended. The “sleep/wake switch” has been shown to be located in the hypothalamus (Stahl, 2002). More specifically, Saper has demonstrated that a sleep enabling area is found in the ventrolateral preoptic nucleus, and that maintenance of the awake state is controlled by the orexin-producing neuron in the posterior lateral hypothalamus (Saper, Chou, and Scammell, 2001).

The significance of the sleep/wake switch being collaterally responsible for the transition between wakefulness and the stages of sleep, as well as the appearance or disappearance of “day to day experienced” consciousness (to the extent that the switch can quench awareness) is paramount in understanding the nature of human consciousness itself (Deikman, 1996). While the hypothalamus may be the centrex of both sleep and wake activities, it is also by design the control of homeostasis in the body. It therefore receives inputs from the reticular formation (which is cooperatively involved in the sleep/wake cycle), basal ganglia, retina, limbic and sensory systems, to name a few. It likewise has connections (outputs) to the autonomic nervous system (via the lateral medulla) where the cells that drive the sympathetic and parasympathetic nervous system are located. Additionally, hypothalamic neurons located in the third ventricle project into the posterior pituitary,

²There may physically come a point in some number of hours where we “can no longer think,” so we express! It may correspond, perhaps, to when our buffer memories that feed the active working memory were full, or these local neurons required time to repair or refresh themselves. This may or may not correspond to the circadian rhythms of our bodies.

while others empty releasing factors nearby the anterior pituitary, causing that gland to release other hormones. With access to all these systems, the hypothalamus can exert control on heart rate, respiration, digestion, and (in a very powerful way) hormone releases. Most importantly, it appears that it may be related to the source of the autonomic timing for the actual phase transitions between conscious awareness and unawareness by some of these connections. The hypothalamus can therefore be viewed as a portion of the seat of consciousness as we know and experience it by virtue of its ability to shut awareness on and off. Without the hypothalamus establishing this level of intrinsic timing, what we experience during consciousness would have no meaning, because to be processed as part of the content of consciousness, it must be cycled through awareness.

Role of Attention

Attention has more meaning when coupled to the actions taking place within the aware state itself. Within awareness, sensory data are accumulated to provide feedback to the foundational knowledge resident in the cortex, and commingled with those data during the conscious, unaware window. This “focus of attention to gather information” or “attention to external or internal stimuli” process appears to be the purpose of the aware portion of human consciousness (James, 1892/1930). This would imply that the attentive process is *always* on within awareness, and that we are attending to something, even when it “feels” as if we were not. Whether we are intensively focused visually on a subject, quietly listening to an inner voice, or just feeling the sun on our face, we are using attention as a marker to point at the subject in focus at the moment. Even when we think our thoughts are drifting, we are attending to the subject matters within the “drift.” The reverse would also appear to be valid: we appear to be only consciously (aware) of those items within our attention (Hardcastle, 1995; Simmons, 2000). Although this is not strictly complete because some information does make it into awareness that is unattended, such as certain shapes and shadings (Braun, 1993; Rock, Linnett, Grant, and Mack, 1992), there is experimental evidence to indicate that voluntary attention is the centerpiece of awareness moment to moment.

Taylor (2002) has alluded to a cyclic processing of conscious moments at a rate that ensures the “continuity of consciousness” itself. That is, consciousness is seamless, and no discrete moments exist, where one scene is missing information as to how it transformed into the next scene.³ In reality, the

³ See Lonky's (2003) idea of blending the biomodal aware and unaware states as “cerebral fusion.”

blending rate must always be high enough that no transformation is sensed, or it must be supplemented by a modulation of information within awareness. Since such rates might vary across individuals, it is more realistic to presume that awareness modulation is an integral part of preserving the continuity of consciousness one moment to the next. In fact, as already indicated, one cannot “attend” to any portion of the processing in the period of unawareness, so that the mind is naturally set up to attend to the “changes” or choices that occur during awareness. This type of modulation would be characterized by establishing a template at any one moment of awareness, and attending to only the changes thereafter. The changes that occurred would then enhance the original scene by adding to or subtracting from that original. Changes could either occur from sensory awareness external to the body and within the viewed scene, or from the archival memory or sensations stored within the mind, but those changes and updates would be required to “keep the image or thought within attention.” During the unaware cycles, no attention can be focused, implying that the mental imagery or thought would ultimately be extinguished without these new changes or modifications. It is similar to the published concepts of “inattention blindness” (Mack and Rock, 1998). This type of imaging or data encoding has historically been referred to as “delta (or differences) modulation” in signal processing, and has been widely used as an algorithm in many other imaging systems (Aziz, Sorenson, and Van der Spiegel, 1993, 1996). Delta modulation is therefore a required attribute as a supplement to rapid awareness cycling ensuring that all individuals will perceive consciousness to be continuous.

To take this empirical model further, it is beneficial to demonstrate that the senses respond with some form of analog to digital conversion. This would support the theorized “difference modulation” concept already discussed. Since the eyes are the sensory processor with the largest amount of work related to consciousness, they are an ideal starting point. This approach would strengthen credence in the proposal that “awareness” cycles are predominant and therefore are what matter most in immediate consciousness, as unaware cycles are reflections of the archival reference of the past thoughts, memories and emotions that “colorize” a landscape. It would also comport with the statements made here and in the open literature that attention is a tool within awareness designed to look for and respond to those differences (Desimone and Duncan, 1995; LaBerge, 1995). Recently, a proposal by Roska and Werblin (2001) outlined an experimentally measured set of signals from the retina that early on establishes a set of discrete or quantifiable features of visualized images. The neural bundles within the retina and optic nerve are layered in strata, and neurons within each stratum respond to at least ten different parallel processed signal sets, each corresponding to a feature of the

viewed image. For example, one set responds only to moving boundaries (edges), and yet another only to uniform areas. With the assistance of amacrine cells, the multiple channels of shapes and areas are able to cross-talk on their way to the optical processing centers of the brain. Other researchers have attributed similar findings to the retina and amacrine cells (Awatramani and Slaughter, 2000; Jacobs and Werblin, 1998). The analog signals picked up by the eye therefore are assembled in the mind through the changes noted within the scene's features, as the content appears to be broken down into discrete buckets of shapes and areas.

These measurements acknowledge, among other things, that linear visual signals are broken down (converted) into categorical "features" (digital), whose properties are cued by changes in value. That the eye therefore updates visual scenes by a change management schema (modulation) appears not to be experimentally in doubt — what is perplexing is exactly how it does that, and the problem may remain unsolved for some time. Also, it has clearly been demonstrated that attention during awareness can affect not only neural activity in humans, but behavior as well. In experiments where human subjects were asked to denote when a previously viewed pattern had changed, performance was strictly related to maintenance of attention through the event, and not upon any physical cues that were given. These experiments highlight that "change itself" is a key event whose presence depends critically on attention (Kastner, Pinsk, De Weerd, Desimone, and Ungerleider, 1999; Ress, Backus, and Heeger, 2000). Hence, awareness of a physical change within a scene can only occur in the presence of dedicated attention (Fernandez-Duque, Grossi, Thornton, and Neville, 2003).

These concepts will benefit from a restating of terms in order to complete the model of consciousness and attention proposed in this approach. First, the periods of conscious but aware moments, and conscious but unaware moments represent the total sum of experienced consciousness in humans, with the "aware content" always providing feedback to the unaware moments. During the unaware periods, the experience sensed in the aware cycle is enriched with the content of our memories and recorded experiences, and subsequently "re-recalled" into awareness. These cycles are repetitive, meaning their continuity can be synonymous with the continuity of consciousness, provided that the frequency of cycling is high enough, and is supplemented by a digital modulation of data within awareness. This paper proposes that this data modulation is related to the sensing of "changes in content features" directed by focused attention during awareness. The only break from this ongoing periodicity is to extinguish awareness, which can happen during sleep. We therefore relate the human aware cycle control to the sleep/wake switch mechanism found in the hypothalamus, and the hypothalamus as at least a transmission hub of human conscious awareness, as we experience it.

It is therefore advanced that the timing for the aware and unaware intervals is provided as part of the autonomic nervous system firings. Based on these concepts, the remainder of this paper will tie the neuro-mechanical properties of visual sensing within this framework, and inspect them for self-consistency. Additionally, concepts will be advanced hinged to the accuracy of the total empirical model that will help ascertain the model's overall completeness.

Visual Awareness Modeling

The eyes are typically thought to be under voluntary control, with the responsible cortical areas located within the frontal cortex (Hanes, Patterson II, and Schall, 1998). However, eye motions occur in two fashions — smooth and slow controlled eye tracking in response to a moving object within the visual field, and in sudden jumps, known as saccades. The saccades themselves are bimodal, that is, there is a set of motions that have very short latencies (less than 100 msec) known as express saccades, and a set of standard, sudden jumps (3 to 5 per second) that occur with high acceleration and deceleration rates that are for all practical purposes ballistic, even though deceleration is accomplished by simply stopping the input to the agonist (acceleration) muscles. The latter saccade movement (standard motion) is completed in 30 to 120 msec, and then stays steady in “fixation.” Fixations can last from 200 to 500 msec (Fischer and Webber, 1993). The express saccades, however, miss the visual target more often than the regular saccades, and have unpredictable gap durations. Whereas visual feedback cannot guide saccades, they appear to be guided by internal feedback of representations of a scene and a newly picked eye position. Most of the feedback originates in the superior colliculus. In short, the saccades appear as autonomic motions, with feedback from the mind to correctly re-align them to various targets. They are a collection of motions with trajectories and corrections resembling distributed data systems (Soetedjo, Kaneko, and Fuchs, 2002).

Both the hypothalamus in the forebrain and the superior colliculus located in the midbrain region involve neural fibers associated with the autonomic nervous system, which is postulated to be the seat of activity for generating both the motions of the eye (saccades included) and, in this foregoing model, the aware/unaware segments of consciousness. Whereas visual and cerebral *feedback* controls where the eye ultimately lands (Everling, Dorris, Klein, and Munoz, 1999; Ferraina, Pare and Wurtz, 2002; Hanes, 2003), the stimulus is proposed in this model to be generated via the autonomic reflex systems (Haushofer, Schiller, Kendall, Slocum, and Tolia, 2002). Likewise, *feedback* from the aware state updates and refreshes stored memories, hidden from visual attention in the unaware state. The two systems are integral to consciousness, and appear potentially related to the same synchrony. Oculomotor

movements and saccades can be essentially both “windows” to conscious timing events, and hallmarks of the aware and unaware state transitions. To demonstrate this potential mathematically, one only need examine the literature for measured event times. These motor movements of the eyes can respond in a tonal fashion to low frequency signals, and in a “twitching” fashion to high frequencies of up to 150 Hz (Carpenter, 1988). As a result of these capabilities, the eyes themselves display several different types of motions, categorically falling into two classes: major saccades and minor saccades.

Major saccades in humans are slow, visually observable motions of the eyes (generally commensurate with head movements) that are larger than 1.2 degrees, and driven by the 5 Hz or less tonal muscle motion. On the other hand, minor saccades can be subdivided into smaller motions, such as mini-saccades or flicks, and micro-saccades or tremors. These motions are not visible to the unaided eye, need special instrumentation to be observed, and are governed by the twitch muscles. The larger saccades typically occur over a 3 to 20 sec period, and are generally infrequent. The minor saccades are more regular, low amplitude movements that have been associated with object or group scanning (Ratliff and Riggs, 1950). The most rapid and regular minor saccadic motion are the tremors, which are typically centered at about 90 Hz, but have been measured in ranges between 30 Hz and 100 Hz (Eizenman, Hallet, and Frecker, 1985; Yarbus, 1967). Their duration lasts 10 to 20 msec. The mini-saccades occur at a rate of 3 to 5 per second for a typical duration of 25 to 30 msec (Ditchburn and Ginsborg, 1953; Sansbury, Skavenski, Haddad, and Steinman, 1973). Both these types of motion will occur during “voluntary” fixation, that is, despite our controlling where our focus (or attention) is centered. Even though the tremors are smaller amplitude changes in eye position, they are enough of a displacement that they should, theoretically, blur vision, but they don't. The mini-saccades have larger amplitudes, occur at theta frequency rates, and have been theorized to be larger corrective displacements to overcome the drifts produced by tremors (Yarbus, 1967; Yarbus and Cornsweet, 1956). Insofar as mini-saccades occur during fixations, and have been correlated to visual attention, their transitions may represent shifts of attention or refocus (Kowler, Anderson, Doshier, and Blaser, 1995; Perry and Zeki, 2000). Their amplitude and frequency should also contribute to a distortion of experienced visual images, but again, they do not in conscious awareness. The saccades themselves also respond to feedback, that is, there are adjustments made movement by movement to new items presented within the field of view. However, the actual time of movement, taken from the appearance of a new item (target), is smaller than the overall fixation period.

Given the lack of visual image perturbations within consciousness by these oculomotor involuntary motions, coupled to the persistent appearance of the

saccades in vision, one must draw the conclusion that either the eye compensates for them, the eye does not register them, or that some complex algorithm is in place within the visual system to employ these motions as visual “enhancers” (Martinez-Conde, Macknik, and Hubel, 2004). There is ample research in the field to provide credence to all of these, and in reality, the debate on the purpose and mechanisms of saccadic involuntary eye motions is far from over. However, in this model, as we have indicated earlier, attention fades to zero during periods of unawareness, and is re-captured during the next aware cycle. Assuming the tremor motions within the mini-saccades are concurrent with the transitions between the mind states (aware and unaware), both driven by similar autonomic responses, the model would propose that any knowledge or sensation of eye motions would suffer the same fate as the loss of attention across the boundaries. With the high repetition rate of the tremors, we would not likely detect the actual transitions either, since they are higher than or equal to the typical flicker fusion rates or the cerebral fusion rates (Lonky, 2003). Coupling this concept together with the fact that the eye is a differential detector that modulates scenes by “changes” only, the transitions between tremor motions (and hence, aware/unaware states) looks for deltas, or changes. The system resembles a rapidly moving kaleidoscope wheel, where slit spacing and width vary somewhat, but are moving fast enough to appear continuous. In this respect, the eye is no different than the tactile senses, which depend on changes as well. In order to note stationary objects, the skin sensors need to move, as we move our fingers to establish the nature of specific items (Ahissar and Arieli, 2001).

Having suggested a correlation between these two processes (visual saccades and aware/unaware transitions within consciousness) as both driven by autonomic responses, but guided by feedback, one should note a very obvious, if not predictable event from the proposal. If one stared at a single object in the visual field to the exclusion of any other, there would be no attention given the other items. Since updates require feedback for “differences” in the scene (normally supplied by all the saccadic motion within the eye), we would expect the other items in the image to disappear after awhile, since during fixation periods, we would only concentrate on that one object. That is precisely what happens in the laboratory, as subjects concentrate during fixation and peripheral objects fade and disappear. The effect was first recorded as the “Troxler effect” (Ditchburn and Ginsborg, 1952).

The emphasis on the “feedback” processes cannot be overstated. Each aware cycle is filled with memories or recall from the unaware portion, but provides “steering” feedback to the next set of “recalls” from subsequent unaware cycles. Likewise, even though ocular motion is stimulated through the autonomic nervous system, the subsequent visual awareness/attention provides feedback to guiding it to a target or compensating for undershoots

or overshoots (Barlow, 1952). To demonstrate that this concept may have validation, consider that the results described by a “feedback targeted model” would then require some measure of latency between the autonomic stimulus of eye motion, and the eye placing a target within its central region, the fovea. Again, these details have been confirmed experimentally. Latency for eye motion is typically the delay time between the true appearance of a target (as inserted into a scene), and the time for a saccade to begin to respond to it. Experimental results have shown some variability, insofar as saccadic latencies can vary between 100 msec (express saccades) to as much as 300 msec. They are usually, however, distributed around 200 msec (Fischer and Webber, 1993). Since the time it takes to actually complete the saccade motion is short (10 to 20 msec), and the signal propagation time for information to flow from the eye to the visual cortex is about 80 msec, it is clear that no direct (on-the-fly) information is guiding eye motion. Rather, the eye response is delayed, gathering feedback to provide correction and more accurately track onto the target (Bridgeman, Van der Heijden, and Velichkovsky, 1994).

Minor saccades have been shown to be approximately conjugate, which is further indicative of autonomic control (Moller, Laursen, Tygesen, and Sjole, 2002). These types of eye motions have also demonstrated that they induce responses via neural excitations in the striate and extrastriate visual cortex, and experimental measurements have shown decreases in neural firings in V1 and excitation responses in V2 and V4 post saccadic movements (Leopold and Logothetis, 1998). Since the “effect” of saccadic motion is therefore present in the visual cortex, one is left with explaining away the lack of disturbance to vision produced, since we do not “see” any jitter in our everyday images. Other authors have surmised a brainstem–thalamus signaling of the cortex that coincides with the initiation of saccades, that essentially is a method for the brain to “clock” their arrival to the eyes (Schlag and Schlag-Rey, 1983). This, in theory, could permit the brain to re-adjust ongoing imagery to avoid distorted vision. However, similar timing mechanisms are very fundamental to the switching between the aware and unaware states themselves, and these alone could provide the needed masking for saccadic motion. Physiological measurements with transcranial magnetic stimulation (TMS) have shown that the image suppression effect of saccades does take place before visual information reaches the occipital visual cortex, and since we know saccadic signals are present in V1, V3 and V4, the act of suppression itself is in concert with the proposed “masking” theory presented here via autonomic switching between aware and unaware states (Ress, Backus, and Heeger, 2000; Santoro, Walsh, and Blakemore, 2004).

This proposed model is now complete enough to test its predictive or correlative abilities by overlaying it onto other experimentally observed “con-

sciousness phenomena,” and their accompanying data. One of the more formidable conundrums in visual (consciousness) science is binocular rivalry. It occurs when two sufficiently different scenes (percepts) are presented simultaneously, one to each eye. What typically ensues within visual cognition is the alternation between the two percepts, as both are contemporaneously possible outcomes for visual awareness. This alternation, which takes place every few seconds, is itself the rivalry, and appears to be the preferential mode for visualizing the two scenes. Alternatively, some combined homologue of the two images that does not alternate is *not* what is seen, and as this may have been the more logical expectation, binocular rivalry has become a theoretical conundrum. For more than one hundred fifty years, researchers and theorists have argued the case for either eye rivalry or stimulus rivalry, since the images on the retina do not change, but their percept does (Blake, Westendorf, and Overton, 1979). Studies have also shown that changes in the target can induce a shift between alternatives, such as contrast modifications, and uneven brightness, as can the projection of the alternating images onto the same eye with some repetition frequency (Fox and Rasche, 1969; Lee and Blake, 1999; Logothetis, Leopold, and Sheinberg, 1996). The resultant experiments to date corroborate both theories (stimulus rivalry and eye rivalry), but they also contradict both. The more current thinking is centered on looking at rivalry as occurring in multiple places within the visual information path (Blake, 1995).

Since binocular saccades demonstrate an “abduction–adduction” asymmetry between their dynamics there may be a difference between the two eyes both in the time of initiation of a saccade to a stimulus as well as in the dynamic field of travel (Collewyn, 2001; Collewyn, Erkelens, and Steinman, 1988). With two different components of information simultaneously sent to the visual processing system, we can pre-suppose that the first image to make it to awareness will be the one exiting “unawareness” first, which will be from the eye with the first targeted major saccade. Whereas the mind knows both images are there, and physiologically, both images are on their respective retinas, we only “see” one in awareness. For the moment, this is not totally dissimilar to the Troxler example. The visual system sees this image as the centrex of the fixation periods until a major disruption occurs, such as a head movement, vergence eye movement, or a sufficiently large discrepancy between each ocular’s saccadic motions (since they are only approximately conjugate), such that the other eye’s focus (image) becomes central. Then, we would expect to revert to the other image at the expense of the first. Not every saccade may be differential, but over a short period of time, one may occur that triggers the shift. Since each saccadic movement is providing feedback of imagery changes to the brain/mind from the past image, an alternating or competitive feedback from the two discordant images would ensue

until fatigue altered the saccadic dynamics. In a sense, the switching appears as a “beat frequency” between the differential movements of the pair of eyes (or a single eye viewing and tracking a pair of overlapping images in monocular rivalry). Due to the eye’s ability to update through “differences,” the original scene would break down in a piecemeal or fragmentary way, and be replaced in a fragmentary build-up of the second (new) image. The process would repeat itself every time a shift in the eye movement refocused the other image. This description is precisely the classical picture presented by binocular rivalry (Levelt, 1965).

Further corroboration of this explanation for binocular rivalry can be found in the neural signal reductions measured in V1, independent of the stimulus complexity. These measurements have been made in an attempt to pinpoint where the image suppression (of one ocular stimulus) takes place (Lee and Blake, 2002). As noted earlier, saccades have demonstrated a similar reduction in neural signals in V1, strongly suggestive that these two processes may be sympathetic. Since little or very small neural activity has been measured in higher order centers (V2 and V4), it appears that binocular rivalry is “settled” at V1 (Tong, 2001). The notion that suppression of one eye’s signal over the other actually produces the rivalry at V1 is offered as a mode of action by theorists because they make a fundamental assumption that there must be a causative neural property aligned with the selection of one stimulus over the other. In reality, this paper is arguing for a different interpretation: visual attention will govern the image selection upon any individual saccadic movement, which will also depend on which ocular stimulus predominates, or was the earliest, or strongest. Then, since an argument has been made in this model that attention within awareness can transition on saccades, it is the loss of that attention, and its re-focusing that produces the shift between each ocular image. The images from both eyes are always there (on the retina and beyond). The selection within awareness has no specific neurological correlate — that is, binocular rivalry is a consequential illusion from the fortuitous shift in attention between eyes. Because saccadic motion and attention have been measured and correlated to show that vision shifts of attention during saccades occur in a “disengage-move-engage” fashion (Posner, Walker, Friedrich, and Rafal, 1984), the transition of rival images is a smooth change, rather than instantaneously abrupt. In cases where the discrepancy between ocular images presented to each eye is small (or quasi-continuous), such as in stereopsis, the default view is a concomitant fusion of those images between the shifts of attention, consistent with image integration. Likewise, non-conforming or discordant images produce a differentiation in imagery, or rivalry.

This explanation withstands the rigors of another visual effect, monocular rivalry, whereas theories on binocular rivalry (whether at the source or physi-

cally at the eyes) cannot explain that phenomena with the proposition that mediation of images is a “neural effect between both eyes,” is decided in VI. Monocular rivalry occurs when an alternating stimulus is presented to only one eye. It is usually in a form of two simultaneous images appearing on one background. The same switching between scenes occurs, only there is no competition between eyes, just in the selection between sources or scenes. In this case, the switching is related only to the “attention” shifts within the one eye, not both, and so the switching might occur at a slower (monocular saccadic transient) rate vs. binocular saccadic transient rates (Hayata and Ino, 1998).

Recent experiments in interhemispheric switching induced by either caloric stimulation or transcranial magnetic stimulation (TMS) have shown that such stimuli can upset the natural switching between images in binocular rivalry (Miller, Liu, Ngo, Hooper, Riek, Carson, and Pettigrew, 2000). More importantly, if the stimulus is delivered to the hemisphere where the current image in awareness is, it can often, but not always, be made to revert to the image in the other eye. The experiments are crucial in pointing out that there is a mechanism working in rivalry that involves a signal (timing) generator that causes oscillations between the two rival states (images that are present on each eye). Current thinking places the source of the timing in the brainstem (Ramachandran, 1994). The model presented in this paper goes one step further and asserts that this type of timing generator is related to both the brainstem-generated autonomic signals for eye saccades, and those for the “aware/unaware” phase transitions. In fact, it would be predictable using this model to predict a hemispheric dependence of predominant images within binocular rivalry in the case where energy pulses were delivered to vulnerable areas of either hemisphere, sufficient enough to cause signal perturbations to saccadic motions (and hence, attention shifts).

Saccades stop during pre-sleep (drowsiness) and non rapid eye movement sleep (Eisensehr, Noachtar, Strupp, von Lindeiner, Brandt, and Buttner, 2001). Complete eye motion (tremors included) stops during phases of deep (stage 3 and stage 4) delta sleep. During rapid eye movement sleep periods, eye motions are restored, although most other physiological muscle interactions are inhibited. Theoretically, REM is the period of active dreaming, and the easiest period of sleep to wake from and to recall dreams. Therefore, some level of consistency to the earlier modeling is achieved, since both eye motion and transitions between awareness and unawareness both cease during deep sleep. If eye motions and awareness (and, consequently, unaware periods) are corollaries of one another, then visual consciousness is governed by the timing interactions of these processes alone.

Experimental confirmation that this is true comes from the work done by Francine Shapiro and others in the field of *eye movement desensitization and*

reprocessing or EMDR. Shapiro (1995) discovered that stress that accompanies traumatic or disturbing thoughts was mitigated as the eyes were forcefully moved, spontaneously and rapidly. Numerous studies (Lohr, DeMaio, and McGlynn, 2003; Wilson, Silver, Covi, and Foster, 1996) have shown that the process appears to work — that is, movement of the eyes can provide clinical improvements in stress related disorders. The process contains elements of identifying a trauma that a patient has experienced and its consequential personal negative association, together with a positive “replacement” affirmation with which the patient wishes to substitute for the negative one. Then a series of full eye movements ensues, in which the patient “processes” the replacement positive imagery for the negative one. There is some reasonable controversy about the studies performed and reported on using EMDR, but these are primarily related to the scientific ability to explain why moving the eyes has therapeutic benefit. However, the process is in wide use in the United States and abroad, and is viewed as having substantive clinical evidence (Maxfield, 2003). Interestingly enough, within the theoretical elements presented in the present model, forced eye movements would precipitate forced attention shifts and focused feedback to the learning mode of “unaware” consciousness. If the model presented is correct as to the coupling of eye motion and aware/unaware cycling, then this directed feedback from EMDR would overshadow everything else within consciousness during therapy. To view this, one need only force eye motion or purposely blink repeatedly during binocular rivalry, disturbing any period of fixation. The observation of rivalry will end immediately.

The arguments applied here to visual consciousness have broad application to the other senses. Since the autonomic timing described is global to each conscious moment, contributions from other sensory portals would be integrated in the same parsed schema as those within the visual sensors. The only significant difference is that eyes uniquely exhibit the tremor and saccadic movements. Experimentation in these areas has shown that some auditory responses can be blended with visual stimuli in the superior colliculus (Peck, 1987). Researchers continue to study the cross-modalities of the senses, and how they affect one another as well as consciousness (McGurk and MacDonald, 1976; von Melchner, Pallas, and Sur, 2000). Most recently, opinions have centered about an integrated model for the senses, rather than the classical view of independent modularity. Imaging technologies have provided insights into the newer view that some traditional pathways thought to be specific to one sense are stimulated by others. It is rare to have “exclusivity” of one sense along a single sensor’s cortical pathway (Shimojo and Shams, 2001). There is also some evidence that the interaction between senses can be tied to eye motion, in some manner that is beneficial to the combined action of the senses (Corneil, van Wanrooij, Munoz, and Van

Opstal, 2002). Recalling the earlier discussion argues for relating the autonomic drive of saccadic motions within the superior colliculus, and the experimental results showing that sensory mode integration is measurable at the same site, can provide compelling interest in the idea that all sensors cooperatively contribute during the awareness cycle.

Discussion

An implementation sequence for visual consciousness has been presented, which itself has significance in the overall process of human consciousness. Given the autonomic basis for the sequencing of the conscious aware and conscious unaware periods, and that each aware cycle drives or updates the subsequent unaware cycle through renewal or alteration of attention, with subsequent feedback, the composite picture represents an “engine” that only has forward motion in providing a time-based conscious experience. That is not to say that pieces of past experiences and memories don’t commingle with current events, but rather that the next sequence of conscious awareness is evolutionarily an extension of the previous one irrespective of the origin of the contents. This process is combined with an information or memory system that advances based on the “changes or differences” present in the current moment as compared to the previous one. Hence, the model proposes consciousness is an evolutionary progression that utilizes (as feedback) the content from each aware cycle, commingled with the archived feelings and memories in the subsequent unaware cycles. The model also proposes that there is a “window” to view this cycling within consciousness, that portal being the eye motions themselves, including ocular tremors and saccades, which have been hypothesized to be tied to the same autonomic pulses as are the aware/unaware periods. The latter movements of the eyes are “reflections” of the autonomic brainstem modulations of the consciousness “system” — not intrinsically a driver of that system.

The motions of the eye would then offer an opportunity to present diagnostic information about the processing of consciousness content, or better yet, the dysfunctional outcomes due to impaired timing from brainstem regions as reflected in those eye motions. Current studies show that eye micro-tremors can be an indication of the general state of consciousness, including the depth of anesthesia, as the number of tremors become fewer as the individual approaches unconsciousness (Bojanic, Simpson, and Bolger, 2001). Along with the frequency of eye tremors, the latency of saccadic motion, range of motion, and fixation stability are among other changes that can prove to be diagnostic. Saccadic anomalies have been used as part of diagnostic testing of patients with multiple sclerosis and Parkinson’s disease (Crawford, Henderson, and Kennard, 1989; Downey et al., 2002). Likewise,

other neurological disturbances such as Huntington's disease and ADHD have had ongoing research showing correlation of established diagnosis with changes in saccadic eye motion (Lasker, Zee, Hain, Folstein, and Singer, 1988; Munoz, Armstrong, Hampton, and Moore, 2003). If, as the theory suggests, the eye movements are reflections of the autonomic timing for the natural interleaving of the conscious aware and unaware states, then changes in that timing could potentially be demonstrated as altered or impaired neurological functions. Incomplete aware timing could possibly disturb neurological signs of awareness and attention, and incomplete unaware timing could affect motor neuron transmissions, among other processes.

It is known that disorders such as Parkinson's disease, Huntington's disease and Tourette's syndrome share a common region of the brain that is associated with some of the motor difficulties, especially in the basal ganglia. Since the origination of the signals causing involuntary eye motion, and the aware/unaware windows of consciousness are tied through or within similar areas, it can be argued that the direct observation of eye movement abnormalities due to these disorders and the corresponding motor symptom appearances are related. However, since the origination points are within the basal ganglia structures and the autonomic systems, these influences are not occurring through consciousness pathways, just through the timing areas of the brain responsible for the bimodal portions of consciousness, aware and unaware. Typically, the basal ganglia can be responsible for true weakness, as noted in some disease states. However, such disorders can display a full range of abnormality, not limited to just "weakness" of motor responses. These include affects of the ease and speed of motion. Therefore, the observations appear to be more complex, and could infer involvement beyond the coincidence of similar brain structure involvement. Surely the psychological issues within schizophrenia are more "cognition" issues than motor issues as are those of ADHD. Measurements made on schizophrenic patients have shown demonstrable changes in saccadic reactions concomitant with impaired information processing (Berger, Nezu, Iga, Hosaka, and Nakamura, 1990). Studies on patients diagnosed with ADHD have shown impairment of fixation and saccadic movements as compared with normal patients (Munoz et al., 2003; Munoz, Gould, Bastain, Israel, Hommer, and Castellanos, 2001). Likewise, administering Ritalin (methylphenidate) appears to strengthen saccadic control and weakens strong fixations (Klein, Fischer, and Hartnegg, 2002). Even though the saccadic and tremor eye movements are windows to the autonomic conscious timing events, and not a basic "driver" of the system, the theory infers that the eye motions are also demarcation movements of the changes of "attention" within consciousness. Insofar as the tremors can be observed as part of the overall eye motion, theoretically, these movements could be studied as to their changes (if any) produced while forcing shifts in attention, or

the reverse. This represents a relatively new area for research: to examine if consciousness mechanisms can be used to alter consciousness dynamics.

The concepts of using eye motion as an "input" to force or maintain attention periods (as described) are partially supported by biofeedback therapy, the EMDR technology discussed earlier, and therapeutic uses of suggestion and trance. In biofeedback, sensors placed on the scalp provide real time readout of portions of an EEG that need alteration. The patient is provided (perhaps) a video input, in which the activity that the patient pursuing evokes a negative or positive change to the EEG. Feedback through learning (via the eyes) allows the patient to see and ultimately feel what paths are beneficial, and what ones are not (Othmer and Othmer, 1992; Sterman and Frair, 1972). The shortfall of EEG biofeedback is often that it is temporary, and only optimized when connected via electrodes. The pathway provided by the eyes to obtain trance-like inductions is well documented in the literature (see Edmonston, 1986). While the eyes are not the only portal used to produce a hypnotic state, they have been used as a primary technique for the production of trance-like states.

There are still many arguments over the classification of trance induction: Is it a science or art-form? However, it is clearer today than even a decade ago that hypnotic trance induction is forming deeper scientific roots (Nash, 2000). There is little doubt that hypnosis has proven a remarkable tool in psychotherapy, primarily because it can be defined as a state of limited awareness which enables access to feelings that may otherwise be less available in fully alert awareness. Hypnosis drives toward a state wherein attention is focused on the therapist, and the feedback to consciousness formed during the aware periods consist primarily of the instructions verbalized by that therapist. Therefore, inputs appropriately provided during the aware portions of consciousness can have a beneficial outcome in behavior or cognition by the feedback methodology advanced by this theory. The induction of a trance provides an environment where this feedback can come almost exclusively from "outside" the individual, and presents a forum for modifying a behavior or releasing a memory or emotion that the "self has prevented" (Spanos and Chaves, 1991). Coupling the concept of the ability to use the directed attention period as "feedback" input to the next "unaware" processing cycle helps us conceive of elements that may support the uniqueness of the state of hypnosis. These areas of therapeutic psychology/psychiatry lend credence to the model's assertion that eye motion, and hence visual consciousness, is extraordinarily related to a consciousness cycling containing two periods of discrete processing that can be externally separated by "attention." In these cases, it would appear that awareness is used for handling inputs and outputs, while unawareness is used for centralized processing.

Since eye motion, attention and ultimately feedback are the major control items within the cyclical consciousness expounded in this model, they are also important to the modification of consciousness. Even though cyclical timing is autonomic, the data elaborated in this paper show that the cycle itself can be disrupted: it occurs in biofeedback, EMDS, trance and other therapies. The recognition that eye motion represents a physical portal to timing is novel, and can allow for extended research in changes produced by drugs as well as changes accompanying various cognitive aberrations. It is interesting to note that Damasio (2003) aptly labeled the conscious process as one that contains the feeling of the body's emotional states, and in reality, we indeed feel all that occurs within us, because we are continuously experiencing it while it is integrated with other sensory stimuli. However, we only report on and talk about what makes it into our "awareness." All of it will ultimately shape how we think, even those portions resident only in our unaware and unattended consciousness because of the regular cycling of the aware and unaware states.

References

- Ahissar, E., and Arieli, A. (2001). Figuring space by time. *Neuron*, 32, 185–201.
- Awatramani, G., and Slaughter, M. (2000). Origin of transient and sustained responses in ganglion cells of the retina. *The Journal of Neuroscience*, 20, 7087–7095.
- Aziz, P., Sorenson, H., and Van der Spiegel, J. (1993). Multi band sigma delta modulation. *Electronics Letters*, 9, 760–762.
- Aziz, P., Sorenson, H., and Van der Spiegel, J. (1996). Using a 1 bit A/D to obtain more than 16 bits of resolution. An overview of sigma delta A/D converters. *IEEE Signal Processing Magazine*, 13, 61–85.
- Barlow, H. (1952). Eye movements during fixation. *The Journal of Physiology*, 116, 290–306.
- Berger, D., Nezu, S., Iga, T., Hosaka, T., and Nakamura, S. (1990). Information processing effect on saccadic reaction time in schizophrenia. *Neuropsychiatry, Neuropsychology and Behavioral Neurology*, 3, 80–97.
- Bischoff-Grethe, A., Proper, S., Mao, H., Daniels, K., and Berns, G. (2000). Conscious and unconscious processing of nonverbal predictability in Wernicke's area. *The Journal of Neuroscience*, 20, 1975–1981.
- Blake, R. (1995). Psychoanatomical strategies for studying human vision. In T. Pappas, C. Chubb, E. Knowler, and A. Gorea (Eds.), *Early vision and beyond* (pp. 1–284). Cambridge, Massachusetts: MIT Press.
- Blake, R., Westendorf, D., and Overton, R. (1979). What is suppressed during binocular rivalry? *Perception and Psychophysics*, 9, 223–231.
- Bojanic, S., Simpson, T., and Bolger, C. (2001). Ocular microtremor: A tool for measuring depth of anaesthesia? *British Journal of Anaesthesia*, 86, 519–522.
- Braun, J. (1993). Shape-from-shading is independent of visual attention and may be a texton. *Spatial Vision*, 7, 311–322.
- Bridgeman, B., van der Heijden, A., and Velichkovsky, B. (1994). A theory of visual stability across saccadic eye movements. *Behavioral and Brain Sciences*, 17, 242–292.
- Carruther, R. (1988). *Movement of the eyes* (second edition). London: Pion.
- Carruthers, P. (1998). Animal subjectivity. *Psyche*, 4. Retrieved May 26, 2004, from <http://www.psyche.cs.monash.edu.au>
- Chalmers, D. (1996). *The conscious mind*. New York: Oxford University Press.

- Collewijn, H. (2001). Interocular timing differences in the horizontal components of human saccades. *Vision Research*, 41, 3413–3423.
- Collewijn, H., Erkelens, C., and Steinman, R. (1988). Binocular coordination of human horizontal saccadic eye movements. *The Journal of Physiology*, 404, 157–182.
- Corneil, B., van Wanrooij, M., Munoz, D., and Van Opstal, A. (2002). Auditory–visual interactions subserving goal-directed saccades in a complex scene. *Journal of Neurophysiology*, 88, 438–454.
- Crawford, T., Henderson, L., and Kennard, C. (1989). Abnormalities of nonvisually-guided eye movements in Parkinson's disease. *Brain*, 112, 1573–1586.
- Damasio, A. (2003). *Looking for Spinoza*. New York: Harcourt.
- Deikman, A. (1996). 'I' = awareness. *Journal of Consciousness Studies*, 3, 350–356.
- Desimone, R., and Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*, 18, 193–222.
- Ditchburn, R., and Ginsborg, B. (1952, July). Vision with a stabilized retinal image. *Nature*, 170, 36–37.
- Ditchburn, R., and Ginsborg, B. (1953). Involuntary eye movements during fixation. *Journal of Physiology*, 119, 1–17.
- Downey, D., Stahl, J., Bhidayasiri, R., Derwenskus, J., Adams, N., Ruff, R., and Leigh, R. (2002). Saccadic and vestibular abnormalities in multiple sclerosis: Sensitive clinical signs of brainstem and cerebellar involvement. *Annals of the New York Academy of Sciences*, 956, 438–440.
- Edmonston, W. (1986). *The induction of hypnosis*. New York: John Wiley & Sons.
- Eisensehr, I., Noachtar, S., Strupp, M., von Lindeiner, H., Brandt, T., and Buttner, U. (2001). Absence of nystagmus during REM sleep in patients with vestibular neuritis. *Journal of Neurology, Neurosurgery and Psychiatry*, 71, 386–389.
- Eizenman, M., Hallet, P., and Frecker, R. (1985). Power spectra for ocular drift and tremor. *Vision Research*, 25, 1635–1640.
- Everling, S., Dorris, M., Klein, R., and Munoz, D. (1999). Role of primate superior colliculus in preparation and execution of anti-saccades and pro-saccades. *Journal of Neuroscience*, 19, 2740–2754.
- Fernandez-Duque, D., Grossi, G., Thornton, I., and Neville, H. (2003). Representation of change: Separate electrophysiological markers of attention, awareness, and implicit processing. *Journal of Cognitive Neuroscience*, 15, 491–507.
- Ferraina, S., Pare, M., and Wurtz, R. (2002). Comparison of cortico-cortical and cortico-collicular signals for the generation of saccadic eye movements. *Journal of Neurophysiology*, 87, 845–858.
- Fischer, B., and Webber, H. (1993). Express saccades and visual attention. *Behavioral and Brain Sciences*, 16, 553–610.
- Fox, R., and Rasche, F. (1969). Binocular rivalry and reciprocal inhibition. *Perception and Psychophysics*, 5, 215–217.
- Fuster, J. (1997). *The prefrontal cortex: Anatomy, physiology, and neuropsychology of the frontal lobe*. New York: Raven Press.
- Hanes, D. (2003). Controlled movement processing: Superior colliculus activity associated with countermanded saccades. *The Journal of Neuroscience*, 23, 6480–6489.
- Hanes, D., Patterson II, W., and Schall, J. (1998). Role of frontal eye fields in countermanding saccades: Visual movement and fixation activity. *Journal of Neurophysiology*, 79, 817–834.
- Hardcastle, V. (1995). *Locating consciousness*. Amsterdam: John Benjamins Press. *Attention versus Consciousness: A distinction with a difference*. Retrieved May 26, 2004, from <http://www.phil.vt.edu/valerie/papers/attencons.html>
- Haushofer, J., Schiller, P., Kendall, G., Slocum, W., and Tolias, A. (2002). Express saccades: The conditions under which they are realized and the brain structures involved. *Journal of Vision*, 2, Abstract, 174a.
- Hayata, N., and Ino, S. (1998). The differences in eye movements and visual impressions in response to static versus motion picture imagery of streetscapes. *Journal for Geometry and Graphics*, 2, 85–91.

- Hirsch, I., and Sherrick, C. (1961). Perceived order in different sense modalities. *Journal of Experimental Psychology*, 62, 423–432.
- Jacobs, A., and Werblin, F. (1998). Spatiotemporal patterns at the retinal output. *Journal of Neurophysiology*, 80, 447–451.
- James, W. (1930). *Psychology: Briefer course*. New York: Henry Holt. (Originally published 1892)
- Kastner, S., Pinsk, M., De Weerd, P., Desimone, R., and Ungerleider, L. (1999). Increased activity in human visual cortex during directed attention in the absence of visual stimulation. *Neuron*, 22, 751–761.
- Klein, C., Fischer, B., and Hartnegg, K. (2002). Effects of methylphenidate on saccadic responses in patients with ADHD. *Experimental Brain Research*, 145, 121–125.
- Kowler, E., Anderson, E., Doshier, B., and Blaser, E. (1995). The role of attention in the programming of saccades. *Vision Research*, 35, 1897–1916.
- LaBerge, D. (1995). *Attentional processing: The brains art of mindfulness*. Cambridge, Massachusetts: Harvard University Press.
- Lamme, V. (2003). Why visual attention and awareness are different. *Trends in Cognitive Science*, 7, 12–18.
- Lasker, A., Zee, D., Hain, T., Folstein, S., and Singer, H. (1988). Saccades in Huntington's disease: Slowing and dysmetria. *Neurology*, 38, 427–431.
- Lee, S., and Blake, R. (1999). Rival ideas about binocular rivalry. *Vision Research*, 39, 1447–1454.
- Lee, S., and Blake, R. (2002). VI activity is reduced during binocular rivalry. *Journal of Vision*, 2, 618–626.
- Leopold, D., and Logothetis, N. (1998). Microsaccades differently modulate neural activity in the striate and extrastriate visual cortex. *Experimental Brain Research*, 123, 341–345.
- Levelt, W. (1965). *On binocular rivalry*. Soesterberg, Netherlands: Institute for Perception RVO-TNO.
- Logothetis, N., Leopold, D., and Sheinberg, D. (1996). What is rivaling during binocular rivalry. *Nature*, 380, 621–624.
- Logothetis, N., and Schall, J. (1989). Neuronal correlates of subjective visual perception. *Science*, 245, 761–763.
- Lohr, J., DeMaio, C., and McGlynn, F. (2003). Specific and nonspecific treatment factors in the experimental analysis of behavioral treatment efficacy. *Behavior Modification*, 27, 322–368.
- Lonky, M. (2003). Human consciousness: A systems approach to the mind/brain interaction. *The Journal of Mind and Behavior*, 24, 91–118.
- MacIntyre, N., and McComas, A. (1996). Non-conscious choice in cutaneous backward masking. *Neuroreport*, 7, 1513–1516.
- Mack, A., and Rock, I. (1998). *Inattention blindness*. Cambridge, Massachusetts: MIT Press.
- Mangan, B. (2001). Sensation's ghost: The non-sensory "fringe" of consciousness. *Psyche*, 7. Retrieved May 26, 2004, from <http://www.psych.e.cs.monash.edu.au>
- Martinez-Conde, S., Macknik, S., and Hubel, D. (2004). The role of fixational eye movements in visual perception. *Nature Reviews Neuroscience*, 5, 229–240.
- Maxfield, L. (2003). Clinical implications and recommendations arising from EMDR research findings. *Journal of Trauma Practice*, 2, 61–81.
- McGurk, H., and MacDonald, J. (1976, 23 December). Hearing lips and seeing voices. *Nature*, 264, 746–748.
- Merikle, P., and Daneman, M. (1998). Psychological investigations of unconscious perception. *Journal of Consciousness Studies*, 5, 5–18.
- Merikle, P., and Joordens, S. (1997). Parallels between perception without attention and perception without awareness. *Consciousness and Cognition*, 6, 219–236.
- Merikle, P., Smilek, D., and Eastwood, J. (2001). Perception without awareness: Perspectives from cognitive psychology. *Cognition*, 79, 115–134.
- Miller, S., Liu, G., Ngo, T., Hooper, G., Riek, S., Carson, R., and Pettigrew, J. (2000). Interhemispheric switching mediates perceptual rivalry. *Current Biology*, 10, 383–392.
- Moller, F., Laursen, M., Tygesen, J., and Sjøle, A. (2002). Binocular quantification and characterization of microsaccades. *Graefes's Archive for Clinical Experimental Ophthalmology*, 240, 765–770.

- Munoz, D., Armstrong, I., Hampton, K., and Moore, K. (2003). Altered control of visual fixation and saccadic eye movements in attention-deficit hyperactivity disorder. *Journal of Neurophysiology*, 90, 503–514.
- Munoz, D., Gould, T., Bastain, T., Israel, T., Hommer, D., and Castellanos, F. (2001). Altered performance on an ocular fixation task in attention-deficit/hyperactivity disorder. *Biological Psychiatry*, 50, 633–635.
- Nash, M. (2000). The status of hypnosis as an empirically validated clinical intervention: A preamble to the special issue. *International Journal of Clinical Experimental Hypnosis*, 48, 107–112.
- Oster, G. (1973, October). Auditory beats in the brain. *Scientific American*, 229, 94–102.
- Othmer, S.F., and Othmer, S. (1992). EEG feedback for attention deficit hyperactivity disorder [technical report]. *EEG Spectrum International*, pp. 1–4.
- Peck, C. (1987). Visual–auditory interactions in cat superior colliculus: Their role in the control of gaze. *Brain Research*, 420, 162–166.
- Perry, R., and Zeki, S. (2000). The neurology of saccades and covert shifts in spatial attention: An event related fMRI study. *Brain*, 122, 2273–2288.
- Posner, M., Walker, J., Friedrich, F., and Rafal, R. (1984). Effects of parietal injury on covert orienting of attention. *Journal of Neuroscience*, 4, 1863–1874.
- Ramachandran, V. (1994). Phantom limbs, neglect syndromes, repressed memories, and Freudian psychology. *International Review of Neurobiology*, 37, 291–333.
- Ratliff, F., and Riggs, L. (1950). Involuntary motions of the eye during monocular fixation. *Journal of Experimental Psychology*, 40, 687–701.
- Ress, D., Backus, B., and Heeger, D. (2000). Activity in primary visual cortex predicts performance in a visual detection task. *Nature Neuroscience*, 3, 940–945.
- Rock, I., Linnett, C., Grant, P., and Mack, A. (1992). Perception without attention: Results of a new method. *Cognitive Psychology*, 24, 502–534.
- Roska, B., and Werblin, F. (2001, 29 March). Vertical interactions across ten parallel, stacked representations in the mammalian retina. *Nature*, 410, 583–587.
- Sansbury, R., Skavenski, A., Haddad, G., and Steinman, R. (1973). Normal fixation of eccentric targets. *Journal of the Optical Society of America*, 63, 612–614.
- Santoro, T., Walsh, V., and Blakemore, C. (2004). The site of saccadic suppression. *Nature Neuroscience*, 7, 13–14.
- Saper, C., Chou, T., and Scammell, T. (2001). The sleep switch: Hypothalamic control of sleep and wakefulness. *Trends in Neurosciences*, 24, 726–731.
- Schacter, D.L. (1996). *Searching for memory: The brain, the mind, and the past*. New York: Basic Books.
- Schlag, J., and Schlag-Rey, M. (1983). Thalamic units firing upon refixation may be responsible for plasticity in visual cortex. *Experimental Brain Research*, 50, 146–148.
- Shapiro, F. (1995). *Eye movement desensitization and reprocessing: Basic principals, protocols and procedures*. New York: Guilford Press.
- Sharaie, A., Weiskrantz, L., Barbur, J., Simmons, A., Williams, S., and Brammer, M. (1997). Pattern of neuronal activity associated with conscious and unconscious processing of visual signals. *Proceedings of the National Academy of Sciences, USA*, 94, 9406–9411.
- Shimojo, S., and Shams, L. (2001). Sensory modalities are not separate modalities: Plasticity and interactions. *Current Opinion In Neurobiology*, 11, 505–509.
- Simmons, D. (2000). Attentional capture and inattentive blindness. *Trends in Cognitive Sciences*, 4, 147–155.
- Soetedjo, R., Kaneko, C., and Fuchs, A. (2002). Evidence that the superior colliculus participates in the feedback control of saccadic eye movements. *Journal of Neurophysiology*, 87, 679–695.
- Spanos, N., and Chaves, J. (1991). History and historiography of hypnosis. S. Lynn and J. Rhue (Eds.), *Theories of hypnosis: Current models and perspectives* (pp. 43–78). New York: Guilford Press.
- Stahl, S. (2002). Awakening to the psychopharmacology of sleep arousal: Novel neurotransmitters and wake promoting drugs. *Journal of Clinical Psychiatry*, 63, 467–468.

- Sterman, M., and Friar, L. (1972). Suppression of seizures in an epileptic following sensorimotor EEG feedback training. *Journal of Electroencephalography and Clinical Neurophysiology*, 33, 89–95.
- Taylor, J. (2002). A control model of the movement of attention. *Neural Networks*, 15, 309–326.
- Tong, F. (2001). Competing theories of binocular rivalry: A possible resolution. *Brain and Mind*, 2, 555–583.
- von Melchner, L., Pallas, S., and Sur, M. (2000, 20 April). Visual behavior mediated by retinal projections directed to the auditory pathway. *Nature*, 404, 871–876.
- Wilson, D., Silver, S., Covi, W., and Foster, F. (1996). Eye movement desensitization and reprocessing: Effectiveness and autonomic correlates. *Journal of Behavior Therapy and Experimental Psychiatry*, 27, 219–229.
- Wood, J., and Grafman, J. (2003). Human prefrontal cortex: Processing and representational perspectives. *Nature Reviews Neuroscience*, 4, 139–147.
- Yarbus, A. (1967). *Eye movements and vision*. New York: Plenum.
- Yarbus, A., and Cornsweet, T. (1956). Determination of the simuli for involuntary drifts and saccadic eye movements. *Journal of the Optical Society of America*, 46, 987–993.