

# The Midbrain Attention-Orienting and Sensorimotor Control Module as an Neurobiological Basis for Scopesception

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## Abstract

This article presents an update to existing literature regarding previous theoretical and experimental attempts to provide a biological basis for the everyday perceptual phenomenon of so-called "scopesception," "scopesthesia" or "staring-detection" — that sudden feeling of being stared-at that compels an automatic orientation of head and eyes to the stimulus. Protruding from the dorsal posterior midbrain, the superior colliculus functions as a sensorimotor processing and orienting module responsive to environmental stimuli. Given the superior colliculus constitutes an ancient visual processing and attention-control center for orienting head-and-eye responses and directing defensive behaviors, neurochemical and network attributes of the superior colliculus and extended circuitry indicate a capable platform for describing the signature components of scopesception. As to what specific mechanisms may register the directed-attention, two lines of reasoning are advanced involving multisensory facilitation/enhancement and the ecological psychoacoustics of subaudible vocalizations. In a clinical capacity, observational decreases of superior-colliculus-mediated saccades (linked to sensorimotor processing) during the therapeutic practice of "eye-movement desensitization and reprocessing" may motivate further etiological insight into biology of trauma and techniques for clinical alleviation of anxiety, hypervigilance and post-traumatic stress.

**Key Words:** superior colliculus, inferior colliculus, corpora quadrigemina, scopaesthesia, eye-movement desensitization, reprocessing, multisensory facilitation, sensorimotor, salience network

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373

## Introduction

The immemorial aphorism of having "eyes in the back of the head" is one of those sayings with a cognate in pretty much every culture; and still today, this figure-of-speech is common the world over. Often considered poetic license, here it is suggested the maxim may derive from an evolutionarily ancient attention-control site on the caudal midbrain of the brainstem. This paper aims to re-establish the concept of *scopesception* from the fringes of parapsychology into a

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neurobiological context re: attention orienting and sensorimotor control in the *superior colliculus* (SC)—an ancient brainstem region exhibiting "the enigmatic ability to make non-conscious decisions about where to focus attention" (Jure, 2019). Consistent across vertebrates, SC detects and responds to multisensory audio-visual stimuli in an organism's field of awareness (Paillard, 1991), and in lower vertebrates represents one of the largest brain regions (King, 2004). The superior colliculus provides a robust platform for "investigating the principles underlying multisensory and sensorimotor processing within a single brain structure" (Doubell *et al.*, 2003). The idea here is that this region represents a storehouse of insight about the nature of organismic experience, information processing, brain organization and development.

Positioned on the midbrain of the brainstem, the bilateral superior colliculi denote a laminated mesencephalic structure involved in the responsive coordination of head-and-eye movements to the detection of activity beyond the immediate attention (Hilbig *et al.*, 1999; Farah & Feinberg, 2000; Lindenmayer & Krebs *et al.*, 2010). In conjunction, the *inferior colliculi* serve as auditory counterparts with a specialized connectivity profile. These four tubercles (in non-mammalian vertebrates: the *optic* and *auditory tectum*, see Belenkov & Goreva, 1969; Bear *et al.*, 2014) are called the *corpora quadrigemina* or "four hills."

This paper provides a proof of concept for the pivotal role of the midbrain attention-orienting module as a biological substrate for the so-called phenomenon of scopesception ('staring detection'). To demonstrate the suitability, an overview of anatomical and functional connectivity features of *superior colliculi* is provided to show how these details may aptly account for previously-posed "scopesceptive" behaviors.

Tabling the concept of "*externally-based, perceptual morphogenetic fields*" (Sheldrake, 2005a), this paper begins by identifying a brain-based description involving retinotopically-aligned, superadditive topographic maps of multisensory modalities in the *corpora quadrigemina*—as a biologically-secure platform capable of bridging the topic into a mainstream arena. Such a link could also encourage further avenues in clinical and computational neuropsychiatry for attending to hypervigilance; improved strategies for diagnostic post-traumatic stress metrics; plus neurochemical explanations for the efficacy of therapeutic methods such as eye-movement desensitization and reprocessing.

This paper begins with a background review of scopesception, followed by an anatomical and functional overview of the superior colliculi as a perceptual-monitoring and visuo-motor directing module indicative of a biological substrate for scopesception. This follows with a summary of previous experimentation that beckons the need for new studies investigating brain regions applicable to scopesception. In the

discussion, possible mechanisms and features further facilitating the phenomenon of scopesception are considered in terms of *superadditive multisensory maps*, *subaudible vocalization*, *ecological psychoacoustics* and the neurochemistry of *extrapersonal space*. In the further reaches, the superior colliculi are considered alongside the onset and perpetuation of hypervigilance—a comorbid factor of posttraumatic stress disorder—as well as chemical mechanisms underwriting the therapeutic efficacy of "eye movement desensitization and reprocessing." Initially, the topic of scopesception may provide the impetus for directing attention to the superior and inferior colliculi (all puns intended); however, this evolutionarily ancient regulatory facet of exteroception may also speak more generally to the binate role of autogenic regulation in organismic processing, and therein, the foundations of experience.

### Scopesception

*Scopesthesia*: the sudden feeling of being stared-at (Wiseman & Schlitz, 1998; Sheldrake, 2005a,b; 2013; Carpenter, 2005; Baker & Stevens, 2008)—also known as '*staring-detection*' or '*unseen gaze detection*'—can be described as the general perceptual ability to detect being visually-tracked or concentrated-on by another, whether locally or even beyond the range of the conventional senses (Braud, Shafer & Andrews, 1993; Atkinson, 2005). If the feeling of being stared-at is called *scopesthesia*, the general capacity for this mode of perception may be regarded as *scopesception*. This involves two components: an individual staring, and another to detect and orient to the stare (Carpenter, 2005; Baker, 2005).

Widespread anecdotal accounts and personal evidence suggest that, beyond the laboratory, the ability to suddenly realize when someone has you in their "focal attention" (Posner & Peterson, 2010) is rather common. For instance, in multiple surveys, seventy to ninety-four percent of subjects report experiencing this phenomenon once to several times (Thalbourne & Evans, 1992; Braud, Shafer & Andrews, 1993; Cottrell, Winer & Smith, 1996; Sheldrake, 2005a). Among these: police, surveillance-personnel, soldiers, special-forces, detectives, martial-artists, bartenders, hunters, wildlife photographers and athletes each acknowledge this sense-ability in their professions. Another study polling school-children posted results with eighty-percent reporting the belief that vision involves 'rays', 'energy', or something similar projecting from the eyes, and another seventy-five percent affirming they could 'feel the stares of other people' (Carpenter, 2005). Anyone who spends extended time with sparrows (and other birds) may offer the same idea. Even if not an autonomous modality, scopesception entails a real and significant phenomenological element of experience involving each of the primary modes of perception (*exteroception*, *interoception* and *proprioception*). This capacity also entails an autogenic regulatory component of

perception. As Radin summarizes: “studies suggest an unconscious sense of being stared-at is a genuine, independently repeatable effect” (Radin, 2005).

Despite diverse practical applications and plentiful real-life reports, scopesception presently resides in the purgatorial domain of a parapsychological phenomenon. Much of this ambiguity may be resolved by a neurobiological naturalization of scopesceptive behaviors linked to the ancient sensorimotor module of the superior colliculus. To be sufficiently explained, a commensurable model requires: a) empirical evidence the directed-attention can act as a causally-efficacious psychophysical force capable of evoking real, physiological and neurometric effects in the receiver; and b) a biological substrate for the signal detection and motor-initiation of saccadic eye-movements to the stimulus source (Braud, 2005; Clarke, 2005). Abundant neurobiological evidence points to the sensorimotor attention-orienting (external-monitoring) module of the superior colliculus (and extended circuitry) to fulfill the second requirement for identifying a biological basis for scopesceptive registry and response.

### Scopesception: Previous Experimentation

While the ‘sense of being stared-at’ has been examined experimentally for over a century, Radin’s (2005) meta-analysis distinguishes two, primary paradigms—one launched by Sheldrake (2003) on ‘*covert observation*’ (see also Baker, 2005); and a second on ‘*remote-staring*’ (Braud & Schiltz, 1991; Braud, Shafer & Sperry, 1993) seeking to determine physiological effects of the directed attention onto a person in another room, unaware of the actual experiment. A third class of experiments by Braud and Schiltz (1991) seeks to identify a cortical electrophysiological signature for the autogenic detection by the brain of a remote stare.

In the *first* model,<sup>2</sup> Sheldrake hypothesizes “the sense of being stared-at involves a process in which a projection takes place through perceptual fields [where] the perceptual projection is not just analogous to, but actually is a field phenomenon” (Sheldrake, 1999). To carry this model, Sheldrake invokes the concepts of ‘*morphogenetic fields*’ and ‘*morphic resonance*’ (Sheldrake, 1981) to describe scopesception in terms of spatially-protracted “perceptual fields” emanating from the brain to great distances linking the perceiver to

<sup>2</sup> Sheldrake’s experimental-design involves two people: one sitting immediately behind another, where the flip of a coin determines whether the person in back (“the starrer”) stares or not at the person in front: (“the staree”). Each trial, the staree attempts to infer whether he or she has been looked-at by a simple yes/no response (Sheldrake, 1999). A larger-scale experiment was repeated at NeMo Science Center in Amsterdam (1995-2002) with data collected from 18,700 “looker-subject” pairs indicating “astronomical” statistical significance with a reliability value in the range of  $p=10^{-376}$  probability the results were due to chance (Sheldrake, 2005a), though Radin notes selective reporting may have played a role in the extremely low p-values (2005). This design has been criticized for a general lack of real-life applicability or “external/ecological validity” (Baker, 2005; Blackmore, 2005).

the perceived in a nested sea of probabilistic fields (Sheldrake, 2005b). In particular, the model of morphogenetic fields and morphic resonance adopts an ‘*extramissive*’ interpretation of vision (Velmans, 2005) as involving a physical projection of visual-signals from the eyes that convey an influence to a target (Braud, 2005; Atkinson, 2005). To address this view from a neural perspective, the present paper identifies a brainstem substrate for scopespection in terms of *internal* retinotopically-aligned sensory-maps in the superior colliculus.

A *second* class of early experiments investigated the physiological effects of “remote staring” through a closed-circuit television feed (CCTV) by measuring changes in electrodermal activity (EDA) time-matched to a directed stare (Braud, Shafer & Andrews, 1993). Here ‘*the starrer*’ and ‘*staree*’ were located in separate rooms connected via one-way CCTV, with the “staree” in a 2000-lb. electromagnetically-shielded room (*ibid*). By removing any direct influence from the conventional senses (like unintentional sounds made by the starrer to induce the staree’s awareness), the goal was to facilitate the influence of the *attention* and *intention* of the starrer on the staree. Instead of asking subjects whether they were being stared-at, the remote-staring paradigm further sought to evade possible artifacts (such as ‘random guessing’ or ‘experimenter bias’) by directly measuring galvanic skin response (GSR) through changes in electrodermal activity (skin-conductance levels: SCL) coupled to concurrent altered-variable combinations (‘face’/‘no-face’) of *images* of the staree from a video-feed on a computer screen in front of the starrer, when prompted to send intentions (Wahbeh, 2021).

Statistical meta-analysis of the results of several trials revealed small but significant differences in EDA/SCL of starees while being watched (Schmidt, Schneider, Utts & Walach, 2004). These results stipulate a patently protractive and nonlocal aspect to the directed attention/intention capable of exhibiting a causally-efficacious effect by inducing changes (intended reactions) in persons situated in a magnetically-encased environment. These findings further bolster previous results indicating changes in EDA/SCL triggered by the gaze of others (McBride *et al.*, 1965; Nichols & Champness, 1971; Leavitt & Donovan, 1979; Strom & Buck, 1979; Wiseman & Smith, 1994; Wiseman & Schiltz, 1999; Schmidt *et al.*, 2004; Baker, 2005) and correlated with autonomic changes in physiology and emotion (Bechara *et al.*, 2000; Nakasone *et al.*, 2005; Dunn *et al.*, 2006; Matejka *et al.*, 2013). “Such reactions may be indicative of a form of knowing or a sensitivity that would seem to fit the outcome of remote attention or intention more closely than that of a visual or other perceptual process” (Braud, 2005). These attributes of scopespection are attributed to Sheldrake’s morphic fields model.

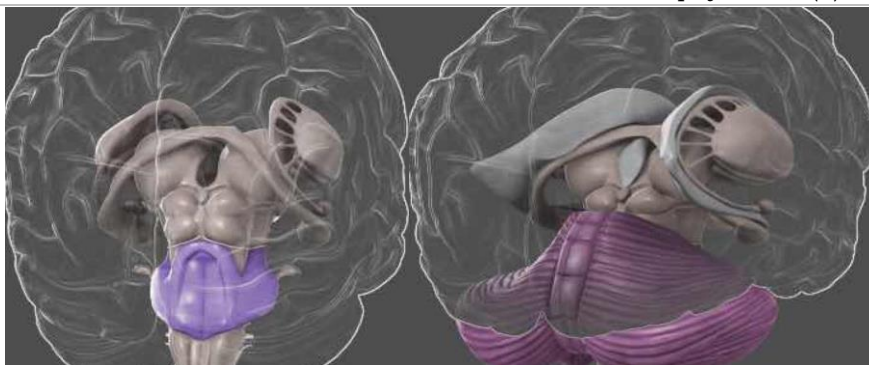
In the *third* method, so far only one known experiment explores a neuroscientific basis for scopespection in the range of cortical electrophysiology. Here, (Baker & Stevens, 2008) expand on the

'remote staring' paradigm of (Braud & Schiltz, 1991) by monitoring EEG activity of 'starees' in an attempt to link 'the remote stare' to a face-specific electrical processing signature. The results of their study determined the effects of remote staring detection on global cortical electrophysiology to be inconclusive, stating that "remote staring detection has an effect upon the global processing of both faces and objects—increasing the GFP in both cases—and does not appear to be a face-specific effect. [...] [This] suggests that remote staring detection apparently does not have an electrocortical processing [signature] in its own right, but rather acts upon any concurrent processing" (Baker & Stevens, 2008).

To improve upon this finding, a neural substrate for scopspection deriving from the midbrain attention-control module of the superior colliculi may be specified as a primary region-of-interest, including face-specific cells in deep laminar layers, as one of multiple modalities (sensory, motor, cognitive) mapped in retinotopic coordination to enhance environmental monitoring and attention-control. In addition, given SC is the only region beyond the cortex where fast-oscillations in the gamma range behave in a manner paralleling in all significant respects with the cortex (Brecht *et al.*, 1998, 1999; Breche, 2001), this points to an intrinsically-coupled *cortico-tectal* (high/low electrical-band) connectivity (Stitt, 2015) linked to the inferior parietal lobe (Clower *et al.*, 2001). This scenario may reframe Baker and Stevens' conclusion by highlighting the entrained subcortical/cortical electrical cross-frequency correlation—in addition to anatomically reentrant (circular) connectivity—between SC and IPL.

### Superior Colliculus: Anatomy & Function

The superior colliculus is a paired, laminated structure comprising two bumps prominent on the posterior aspect of the midbrain surrounding the pineal body (Dean & Westby, 1989; Paxinos & Watson, 2020). From a sagittal view, the superior colliculi are located on the rostrocaudal axis between the cerebral aqueduct and dorso-anterior cerebellum. The superior colliculi reside immediately anterior the medial geniculate thalamic nucleus and periaqueductal gray area, and ventral to the *posterior commissure* (King, 2004). Along with the *inferior colliculi*, these two pairs of nuclei form the "four hills" of the *corpora quadrigemina*, as depicted in the following diagram.



Caption: (left) caudal view of brainstem complex (incl. medulla; pons; midbrain; corpora quadrigemina; thalamus; caudate nucleus; pineal body; amygdala; hippocampal formation (incidentally, *pons* labeled in *lavender*); (right) axial view of brainstem complex including cerebellum (*in purple*)—with superior colliculi above and inferior colliculi hidden. Source: Cold Springs Harbor Labs, Brain Learning Application, accessed 2019.

Largely conserved in function across the vertebrate phylum *Chordata* (amphibians, reptiles, birds, fish, mammalian tetrapods), the superior colliculi (née *optic tectum* in non-mammalian vertebrates) serves as the oldest visual processing system in the brain<sup>3</sup> (King, 2004; Fuchs & Ansorge, 2012) and a prominent attention and sensorimotor module mediating the detection of evolutionarily-significant stimuli that require immediate action such as: approach/avoid behaviors (Castro-Alamancos & Keller, 2011); motor movement precipitation (Sprague & Meikle, 1965; McHaffie *et al.*, 2005); covert triggering of attentional shifts without overt movements (Robinson & Kertzman, 1995; Ignashchenkova *et al.*, 2004; Katyal *et al.*, 2010); and defensive behaviors including sensorimotor control of arm movements for blocking (Himmelbach, 2007); escape response; cowering; and exaggerated startle (DesJardin *et al.*, 2013).

The functional profile of human SC also includes emotional, autonomic and cognitive capacities (Merker, 2007; Krauzlis *et al.*, 2013) as well as socially motivated interactions, cues and decisions (Liddell *et al.*, 2005; Wei *et al.*, 2015). For instance, visual signals originating from superficial and deeper layers of SC project to the amygdala via the *thalamo-limbic* intermediary of the *pulvinar nucleus*—e.g., face-specific cells in deep layers precipitating emotional responses via visual stimuli cohesively encoding facial images (Soares *et al.*, 2017; Diano *et al.*, 2017) and implicit emotional expressions (Davis, 1992; Fanselow & Gale, 2003; LeDoux, 2003)—known to strengthen in connectivity during the detection and processing of visual stimuli and fear-based responses (Morris, Öhman & Dolan, 1999; Pessoa & Adolphs, 2011).

<sup>3</sup> SC is phylogenetically older than lateral geniculate nucleus (LGN), and dominant destination for retinal projections in lower mammals. LGN is the dominant target for retinal information in higher mammals, particularly primates.

Such connectivity provides a valuable evolutionary mechanism for stimulating physiological vigilance in an emotionally salient manner, including motor initiation of intrinsic action-protocols (defensive, instinctual) for responding to subconsciously perceived visual cues from the environment. Given “one of the most important functions of any nervous system is to sense the external environment and to control movement of the body within it” (King, 2004), the superior colliculi enable a key advantage via the ability to “acquire information about the world” (King, 2004) and detect interesting or aberrant activity in the visual field, and to respond when appropriate with adaptive and defensive motor/action repertoires (facultative action policies) promoting survival. These descriptions reinforce support for the central “scopespective” role of SC in facilitating alerting awareness to the presence of a starrer. For sensory signals to trigger movement, a functional “interface between sensory and motor processing is required” (King, 2004; see also Hilbig *et al.*, 1999). This interface is supplied by the critical sensorimotor hub of SC via transduction of multimodal afferent sensory inputs into efferent, saccadic motor outputs responsible for orienting responses of the eyes, head and torso to salient external stimuli (Robinson, 1972; Wurtz & Mohler, 1976; Krebs *et al.*, 2010).

In terms of motor-response, the superior colliculi project to the colliculospinal (tectospinal) motor-tract to modulate aspects of guiding rapid head-and-eye movements to foveate toward a stimulus (Bear *et al.*, 2014), along with direct projections to the spinal cord to invoke responses to stimuli prior to cognizant cortical processing (Petras, 1967). This is made possible in part by large multipolar motor-output neurons in deep laminar layers of SC whose axons extend to pre-dorsal bundle fibers involved in the control of visual orienting processes (Zhu & Lo, 2000; May, 2006) including preparation and execution of saccadic eye-movements for tracking objects in the visual field (Wurtz & Mohler, 1976; Takakusaki & Okumura, 2008), and encoding the behavioral relevance of stimuli for target selection during visual search (Himmelbach, Erb & Karnath, 2007). This includes efferent connectivity with the nigrostriatal dopaminergic pathway, responsible for sensorimotor integration and arousal (Hopkins & Niessen, 1976). Intermediate and deep *oculomotor* layers in SC are also a major target for inhibitory inputs projecting from the dorsolateral *substantia nigra (pars reticulata)* involved in regulating posture and movement, like halting the motion of fright-response to reduce detection, etc. (King, 2004; Okumura & Takakusaki, 2008; Holmes, 2011) — thus making the *corpora quadrigemina* of particular evolutionary importance for contributing a speed-of-response advantage necessary for instinctual and survival behaviors (Huffman & Henson, 1990).

In terms of cytoarchitecture, the laminar structure of the superior colliculi contains seven alternating, fibrous and somatic layers subdivided into *superficial*-, *intermediate*- and *deep*-layered



cyto/myelo-architecture (Wurtz & Albano, 1980; Sparks & Hartwich-Young, 1989; Huerta & Harting, 1984; Tardif, Delacuisine, Probst & Clarke, 2005; Berman & Wurtz, 2010) where each layer contains morphologically-unique neurons with distinct physiological-response properties, connectivity patterns and molecular profiles, thus providing “points of interconnection between many circuits serving a range of sensory, motor, and cognitive functions” (Krauzlis *et al.*, 2013). For example, in *superficial* layers (sSC), cells located rostrally exhibit robust bursting activity during visual fixation and small-amplitude saccadic eye movements (Krauzlis *et al.*, 1997; Gandhi & Katani, 2011), called “*fixation neurons*” (Munoz & Wurtz, 1993). These neural clusters reflect activity associated with the act of staring. So too, neurons in *intermediate* layers (iSC), dubbed “*burst neurons*,” discharge “a high-frequency burst of action potentials” just-before and during saccades (Furlan, Smith & Walker, 2015). This activity substantially diminishes after stimulus extinction, indicating a preparatory role in saccade selection (Horwitz & Newsome, 2001). Nerve cells located caudally in *deep* layers (dlSC) termed “*visuomotor prelude neurons*” contain pre-saccadic, low-frequency ‘build-up’ activity involved in saccade preparation and target selection that “fire continuously from target onset until a saccade is initiated” (Munoz & Wurtz, 1995).

To improve the causal efficacy of these processes, each laminar layer of neurons in SC encodes a mutually-aligned retinotopic map of the surrounding environment per each sensory modality (Robinson, 1972; Alonso & Chen, 2009; King, 2004), thus enabling a topographical alignment of superimposed maps of multisensory representations—e.g. audiovisual, spatial and somatic (body) signals—between superficial and deeper layers (Stein *et al.*, 1995; Doubell, 2003).<sup>4</sup> For instance, sSC neurons encoded in a common retinotopic coordinate frame “pool the inputs from multiple V1 neurons to form a feature-agnostic saliency map which may then be relayed to other brain areas” (White *et al.*, 2017; see also Hyde & Knudsen, 2002). This visual saliency map encodes sensory signals via center-surround inhibition (as a map of stimulus position) for encoding “stimulus conspicuity” in a retinotopic-aligned visual scene sensitive to “low-level features such as brightness, colour, oriented edges and motion” from the rod-rich areas of the peripheral retina. This information feeds into priority selection mechanisms in intermediate/deep layers affecting the precipitation of saccadic and

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<sup>4</sup> “This principle also extends to the optic tectum in non-mammalian vertebrates and is common to many senses, including infrared and visual representations in pit vipers, and electrosensory, lateral line and visual representations in certain species of fish.” (King, 2004). This may reveal more insights into the full capacities or capabilities of SC processing characteristic of staring-detection, including vibrissal processing in the superior colliculi (e.g., Favaro *et al.*, 2010) and any potential artifacts in genetics and processing-features also possibly contributing to scopesceptive behaviors and efficacy, given humans are (one of?) the only species to have dropped their whiskers. This may also suggest a partial attenuation of scopesceptive communication in humans proportional to individualized cognition.

microsaccadic eye movements (Krauzlis *et al.*, 2013; Veale *et al.*, 2017)—e.g. to inform amplitude and direction of visually-guided rapid saccadic orientation (of eyes, ears, head) to the location of salient stimuli in the visual field (Cynader & Berman, 1972; Kustov & Robinson, 1996); to inform slower, "pursuit eye-movements" for tracking moving visual targets (DuBois & Cohen, 2000); and for initiating orientation of the attention to faces and bodily-movement activity (Rosa Salva *et al.*, 2015; Mares *et al.*, 2016).

Neurons in deeper layers of SC also contain audiovisual, somatosensory (Sparks & Hartswich-Young, 1989; Ghose *et al.*, 2014) and visuomotor neurons (Waitzman and Ma *et al.*, 1991; Afonso, 2017) exhibiting preferential responses to the presentation of multimodal stimuli over unimodal components (Meredith & Stein, 1996). These neurons receive "convergent projections from all cortical saccade-related areas including PFC" (Everling & Johnston, 2013) and extrastriate cortex (Krauzlis *et al.*, 2013) for the purpose of coordinating visual, auditory and tactile responses<sup>5</sup> (May, 2006); planning premotor orienting activity (Casagrande *et al.*, 1972; Grantyn & Berthoz, 1985); inhibitory control of saccade shifts from prefrontal cortex, prompting efferent projections to a brainstem circuit modulating head-and-eye saccades (Sparks & Nelson, 1987); and the triggering of autonomic vigilance plus other fear-based behavioral/physiological responses. This suggests SC performs both multisensory and sensorimotor processing (Cooper, Miya & Mizumori, 1998).

Additionally, deep-layers contain a goal-directed (top-down) '*priority map*' that "integrates information from a bottom-up saliency map with task- and goal-relevant information" (Veale *et al.*, 2017; see also Fecteau & Munoz, 2006) as well as visual information processed in the primary visual cortex. Within these maps, neurons are organized according to movement-field centers (Cheng & Furlong *et al.*, 2015) to facilitate a correlative motor map of head/eye movements (Gordon, 1973; Sparks, 1988; Wallace *et al.*, 1996) for targeting specific coordinates of a salient stimulus in the retinotopic spatial field to then direct motor responses toward or away-from an individual, etc. (Hilbig *et al.*, 1999; Isa, 2002; Krebs *et al.*, 2010); or to inhibit saccadic impulses in order to remain discrete (Sparks, 1999; Farah & Feinberg, 2000).<sup>6</sup>

<sup>5</sup> For instance, neurons in intermediate layers involved in the reception and processing of sensory inputs and sensorimotor functions like hand-eye coordination project to the anterior intraparietal sulcus, shown to differentially respond in activation while grasping at objects (Davare *et al.*, 2011; Borra *et al.*, 2012; Zubricky & Das, 2022).

<sup>6</sup> Neurons in rostral regions respond to stimuli in front of the body (including face), and neurons in caudal regions activating *prior* to larger amplitude saccades and gaze-shifts to stimuli in more peripheral locations and behind the body (King, 2004). Similarly, "neurons in the medial region of the nucleus respond best to high visual or auditory stimuli or to stimulation of the upper part of the body, while those in the lateral region represent low or ventral stimulus locations" (*ibid.*).

Altogether, these overlapping retinotopic maps generate an enhanced multisensory landscape enabling an environmental-monitoring capacity at the subcortical level. This scenario facilitates faster orientation to objects in the visual field as well as the initiation of defensive behaviors including covert suppression and regulation of 'physiological vigilance'. As King explains, "the registration of the different sensory maps—and therefore of the individual receptive fields of those neurons—would appear to be essential [in localizing] biologically-important events including [potential threats such as] predators or prey that attempt to avoid detection by using camouflage and stealth" (King, 2004). The evolutionary imperative of sensory monitoring essential for defensive and survival behaviors makes SC of acute importance (Anderson, Porrill & Dean, 2012; see also Petras, 1967; Huffman & Henson, 1990; Hirokawa *et al.*, 2011).

## Discussion

*There would be an evolutionary advantage in being able to detect another's gaze; and in fact we, and other species, have visual systems designed to be good at this. A pair of eyes is a salient stimulus. We can pick it out easily from complex scenes, attention is automatically drawn to it, and eye movements are made towards it without prior identification.*

Blackmore, 2005

383

The orienting of head, eyes and torso to salient stimuli in an individual's visual field refers to what is called *phasic alertness* (Sokolov, 1963) and is defined alongside the concept of *tonic alertness*, referring to autonomic/physiological vigilance and sustained attention (Oken, Salinsky & Elsas, 2006). Together, these two modes of awareness/attention parameterize the autogenic (or internally self-organizing) aspects of scopesception (i.e., the ability to detect the concentrated gaze of another). In essence, there are three features required to explain scopesception: a) empirical evidence for the directed attention as a causally-efficacious psychophysical force capable of evoking physiological and neurometric effects on another organism; b) a neural substrate for the signal detection and motor-initiation of saccadic eye-movements to the stimulus source; and c) a causal or mechanistic explanation linking the first-two stipulations. While the plethora of experiments measuring SCL-responses linked to a staring-effect provide precedent for the first requirement, physiological and neurometric effects alone do not resolve regions-of-interest (including secondary signaling circuits), nor a mechanism for the registry of directed-attention. To address the second requirement, this paper identifies the primary role of the superior colliculi, located on the dorsal midbrain of the brainstem, for addressing regulatory attention-control behaviors linked to scopesception. What remains to

resolve is an account of how the directed attention of an organism registers in the sensory fields of another. The following topics suggest additional lines of reasoning to help hone in a causal mechanism for staring-awareness and response *a la* predictive processing and the variational free-energy principle (Friston, 2010); *superadditive multisensory* maps; and a broader discussion of directed-attention in terms of *subaudible vocalization* and *ecological psychoacoustics*, including the neurochemistry of *extrapersonal space*.

## Predictive Processing & the Free-Energy Principle

Given the evolutionary and biological imperative for regulatory dynamics, where the present paper features the exogenous attention-control module of the superior colliculi as a bottom-up regulatory (autogenic) perceptual operation, it is also natural to expect in SC a top-down predictive model of the environment (per the 'good regulator hypothesis': Ashby, 1947) for enhancing the awareness of prioritized and salient signals in the environment based on models of past memories and cognitive neural maps etc., thus enhancing sensitivity to details of which a conscious being may otherwise be inattentive or unaware. Further support can be derived from evidence that the primary visual system maintains a head-centric, 360° model of surroundings using multimodal cues and inferential predictions to represent areas beyond visible-field awareness (Shioiri *et al.*, 2018). Given the innate convergence of top-down and bottom-up causal operations in perception (Friston, 2010), it can be further posited that inferential (top-down) processes in the midbrain attention-control network heighten detection of subtle changes in the environment, including when/where someone is looking/staring. As Jure explains:

"Due to its strategic location as a first line visual and multisensory structure to receive environmental input and its multiple direct connections from the cortex, the SC is in the interphase of several complex processes, [one of these being] bottom-up and top-down attentional interplay" (Jure, 2019; see also Merker, 2013).<sup>7</sup>

Advances in neuro-computational models suggest the brain operates as a predictive engine to minimize prediction-error (Hohwy, 2013; Clark, 2017; Smith *et al.*, 2020). This dichotomy involves autogenic neural operations *a la* the free-energy principle driving Bayesian predictive processing and perception (Friston, 2022). The essence of Bayesian statistical models and the Bayesian brain hypothesis is based on the updating of prior beliefs in light of new

<sup>7</sup> These dimensions are essential not only to process ongoing information but also to mentalize actions (Corbetta *et al.*, 2008); mental time travel; and develop complex representations of the self (Fabbro *et al.*, 2015).

information to produce a "posterior" expectation value, as a basis for anticipatory and predictive operations.<sup>8</sup>

Applying a Bayesian approach to the evolutionarily-ancient sensorimotor attention control module of SC (Diggle, 1984; Busetto & Buhmann, 2009; Beaumont, 2010; Blum *et al.*, 2012) may provide a subcortical exemplar for predictive coding and the minimization of variational free-energy in conjunction with the salience network. Other supporting evidence comes from data finding "deep SC neurons use their sensory inputs to compute the probability that a target is present" (Anastasio *et al.*, 2000); and that "even though the target of the next saccade may not yet be selected, each map contains information about the probability of a visual location being next foveated" (Krauzlis *et al.*, 2013).

### Superadditive Multisensory Facilitation (Enhancement)

To consider how the concentrated and directed attention may register as a salient stimulus in a recipient, one "easy" solution is that this may arise as a superadditive epiphenomenon of the enhanced result of retinotopically-organized multisensory signal processing of the brainstem (*superior colliculus*) and parietal cortex (*inferior parietal lobe*), as well as subcortical sites like the hippocampal formation.

385

Retinotopically-aligned topographic maps "lie in spatial register across the collicular layers" (Castro-Alamancos & Keller, 2011), providing a superadditive platform for adaptive sensorimotor responses and predictions within the environment (Sprague *et al.*, 1973; Ingle, 1973; Butler, 2011; Isa & Hall, 2009). This common retinotopic coordinate frame enables converging modality-specific inputs to SC (sensory: *visual; auditory; somatosensory; cerebro-vestibular*; cognitive: *salience; priority*; and motor) enabling an enhanced (or *superadditive*) neural response evoked by combining two or more stimuli of one modality with input from another modality that is larger (more-sensitive) than either stimulus alone (Fraiberg, 1977; King, 2004).<sup>9</sup>

This *superadditive* synergy of multimodal cues is called *multisensory facilitation*. As Doubell explains, "this enables each of the modality-specific cues associated with a common source to activate the appropriate region of the motor map for encoding orienting movements toward the source of stimulation. [...] It also allows multisensory inputs to be synthesized by neurons in a behaviorally useful way [such that] different modality-cues arising from a common

<sup>8</sup> "The brain can change its model to fit the incoming sensory stream, or change the incoming sensory stream to fit its model (for example, by moving). Perception, on this account, is constituted by the brain's expectations as to the external causes of its perceptual input" (Friston, 2006).

<sup>9</sup> For example, non-conscious integration of vision with somatosensory input further allows the differentiation between the self and environment (Fraiberg, 1977).

source can lead to response enhancements” (Doubell *et al.*, 2003; see also King & Palmer, 1985; Meredith & Stein, 1996). Superadditive processing heightens spatial-sensitivity and ability to detect more-nuanced signals in the environment. This bolsters the efficacy of multisensory integration to hasten sensitivity and reaction times to the orientation of attention and the initiation of reflexive movements (i.e., scopesception). Such an information-rich signaling milieu of specialized processing enhancements may provide a partial explanation for the detection of directed-attention.

### Tactile/Somatotopic/Facial

One particular modality modeled in retinotopic maps in SC involves neurons responsive to somatosensory inputs labeled on a somatotopic map in the ventral subregion of SC, relayed from the *zona incerta* of the thalamus (Weldon & Best, 1992). If evidence for the selective triggering of a *somatotopic map* in SC deep-layers can be linked to an externally concentrated gaze, this would aid in identifying a substrate for Sheldrake's “extramissive” view. Other evidence suggests an excitatory somatotopic pathway based on dense, direct afferent projections from the trigeminal nucleus and dorsal column nuclei to deep-layers of SC (Nicolelis & Lin, 1992; see also Sparks & Nelson, 1987), and then projecting to the *lateral amygdala* via *pulvinar* to inform emotional responses re: visual stimuli concurrently encoding facial images and emotional expressions (Rafal *et al.*, 2015; Diano *et al.*, 2017; Fanselow & Gale, 2003; LeDoux, 2003).<sup>10</sup> Additionally, there is a small commissural projection beginning in deep-layers of SC (significant in face representation and central vision) where axons pass to contralateral colliculi via the tectal commissure, then back to deep-layers of SC (Harting, 1977). In theory, face-specific cells and “fixation neurons” could also become entrained between brains (Wass *et al.*, 2020; Haresign *et al.*, 2022). Another line of experimentation might investigate whether differential activity of face-specific cells (co-active when staring) might prompt a detectable electrical signal in recipients.

### Audiovisual

Likely the most-evident factor in a mechanism for scopesceptive registry is literally right underneath SC. Given “in the natural world, the ability of both predator and prey to capture the acoustic signatures of faint sounds and detect their repetition is essential for survival” (Luz & Valente, 2012), spatial hearing and auditory spatial location are of key import. “Unlike vision, perception of sound does not require the listener to be oriented in a particular direction. [...] These

<sup>10</sup> The anterior pretectal nucleus of the pretectal complex also has connections with SC and other areas associated with sensory functions, and may play an additional role in somatosensory processing (Rees & Roberts, 1992).

characteristics make sound highly suitable for monitoring and alarm applications" (Walker & Kramer, 2004).

Neurons originating in the inferior colliculi synapse with both superficial sensory- and deep motor-layers of SC (Edwards *et al.*, 1979; LeDoux *et al.*, 1985), generating an auditory spatial map conformed to the visual template in superficial layers (Doubell *et al.*, 2003; Hyde & Knudsen, 2002). Also notable, the *auditory belt* (A2) picks up imperceptible patterns akin to movement that combine with visual signals in the superior colliculi (Purves, 2004). Evidence for auditory influence on visual responses in superficial-SC suggests visual form discrimination may be improved by concurrent sub-audible activity (in local field potentials) and stimuli where selective enhancement of certain activity (i.e. concentration) could be mediated through a gain-control mechanism modulating visual responses (spiking activity) "that serves to boost the salience of the visual signal" (Ghose *et al.*, 2014) when auditory and visual stimuli are presented together (Boehnke *et al.*, 2011). Such a mechanism may serve to amplify visual signals under weak, ambiguous or noisy conditions, thus improving detection thresholds, discriminability and localization.

Considering auditory signals are processed faster than visual signals in the brain (although the speed of light is faster than the speed of sound), the auditory belt and inferior colliculi may contribute further sensitivity and accuracy to the superior colliculi in terms of the detection of locally-salient environmental signals. Enhancement of detection specificity by audiovisual combination may also likely contribute to the registry of an external, directed-attention.

### Attention and Intention

*"The most important of the consciousness-related processes implicated in the staring detection effect are the fundamental ones of attention and intention."*

Braud, 2005

While these explanations suggest ways that staring-specific activity may be received from one organism to another, the question remains as to what enables and facilitates the transmission and causal efficacy of directed attention. As Velmans explains, "directional information flows operat[ing] unconsciously would explain the finding that skin resistance measures indicate stare detection more sensitively than subjects' verbal reports—and would also make sense of the fact that one might 'feel' another's focused attention without having any knowledge of how that feeling comes about" (Velmans, 2005). This "extramissive" view suggests the directed attention acts as a causally-efficacious force (or frequency) capable of inducing somatic,

physiological and tactile impacts when focused on a target,<sup>11</sup> and that some contingent of conscious experiences “arise from processes in the mind/brain interacting with the surrounding world” (Velmans, 2005). Given the “demands for sustained attention caus[ing] elevations of blood pressure and release of catabolic hormones” (Lee, 2019), this may also cause a change in tacit energy signatures (or *local field potentials*) picked-up by autogenic detection of salient objects linked to a directed-attention. This would shed further light on the subtle capacities of perceptual awareness and the enactive nature of directed-attention as a “mutual interaction between the sensorimotor capacities of the organism and its environment” (Wilson & Foglia, 2011).

Preliminary evidence in line with EDA-CCTV findings further suggests *intentions* may be carried by the attention to evoke characteristic affects and emotions along with heart-rate variability; electrodermal activity; and electrocortical dynamics—both when the starrer is positioned locally *and* remote (Baker & Stevens, 2010). These findings suggest a directed attention may serve as a causally-efficacious *psychophysical* force.

### Ecological Psychoacoustics

Another possible conduit may emerge from exploring the nature of projected thought and language. Reframing the common comment to unreserved friends that “when you think out-loud it’s called talking!” – seriously considered, this idea suggests “thinking may be [a form of] subaudible speech” (Markowicz, 1972). Pending Sheldrake’s morphic fields model, if evidence can be found for electro-physiological signatures of subaudible speech,<sup>12</sup> it may be possible to frequency match distinctive changes in autonomic rhythms and electroencephalographic activity in a receiver to determine if the directed-attention can be partially interpretable in the target. One line of evidence involves the functional organization of frequency and location processing in the inferior colliculi and lateral geniculate nucleus of the thalamus, including registry of natural vocalizations (Moerel et al, 2015; Lyzwa *et al.*, 2016). Following this train of thought prompts the suggestion that the directed-attention may induce a sort of carrier-wave mode for subaudible vocalizations.<sup>13</sup> This idea may be improved by the fact that the inferior colliculi register amplitude and frequency modulation—more-so longer-ranged amplitude (Holstrom *et al.*, 2010). Unpacking these details may reveal another factor for

<sup>11</sup> One factor may involve the frequency of “fixation neurons” in the sender. The stare of another could also impact the frequency of the local electromagnetic field surrounding an individual.

<sup>12</sup> Individual words spoken into ionized water have shown to vary in characteristic patterns of frequency (Emoto, 2004), also suggesting some sort of projected electrical signature corresponding with certain types of language.

<sup>13</sup> Ecological psychoacoustic soundscape analysis examines primary auditory cortex response to subaudible sounds (infrasound), and thus may be able to make contributions to a mechanistic understanding of scapesception.



registering the directed attention as transmitted (when staring, etc.) in the form of subaudible psychoacoustics. In a practical sense, a scopesceptive registry is aided by the autogenic ability of regulatory processing to distinguish subtle forms of body language, also conveying subtle information and intent.

### **Neurochemistry of Behavioral Activation in Extrapersonal Space**

Another related topic involves how "the brain constructs not one but various functionally distinct representations of space" (Scarpazza, di Pellegrino & Làdavasa, 2014). One of these entails an "extrapersonal" or "peripersonal" space representation<sup>14</sup> referring to the domain and range surrounding the body where objects can be grasped and manipulated (Scarpazza, di Pellegrino & Làdavasa, 2014). This involves a ventral circuit for the exogenous allocation and reorienting of attention in space (Committeri *et al.*, 2007). As Previc explains, "brain systems relying on acetylcholine are also involved in behavioral activation in extrapersonal space (McGuinness & Pribram, 1980) and in extrapersonal functions such as visual orienting, vigilance, and episodic memory" (Previc, 1999; see also McGaughy, Kaiser, & Sarter, 1996; Harder, Baker & Ridley, 1998; Perry, Walker, Grace & Perry, 1999).

In addition, "[dopamine] systems are critical for registering the salience of and responding to all distal motivational stimuli, even aversive ones" (Previc, 1999; see also Berridge & Robinson, 1998). "The mostly parasympathetic actions of both ACh [acetylcholine] and DA [dopamine] (Velasco & Luchsinger, 1998) are consistent with the heart-rate deceleration during vigilance and orienting toward distal stimuli" (Graham & Clifton, 1968; Previc, 1999) as demonstrated by cholinergic inputs activating nicotinic acetylcholine (nACh) receptors on projection neurons in the intermediate layers of SC that facilitate the initiation of orienting behaviors (see Wichmann & Starke, 1988). Given hypothalamic (A13) dopamine neurons also innervate SC (e.g., Woolrych *et al.*, 2021), such findings could be further developed to explain a chemical mechanism for the effectiveness of eye-movement and desensitization therapy.

### **Further Reaches: Therapeutic/Clinical Applications**

Establishing a correlation between SC and scopesception may also provide clinical insights into anxiety, particularly in studies of hypervigilance and PTSD. Hypervigilance is often a symptom of PTSD and anxiety characterized by SC-related behaviors such as heightened

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<sup>14</sup> "Awareness of extrapersonal space is based on the integrity of a circuit of right frontal regions (ventral premotor cortex and middle frontal gyrus), and superior temporal regions, whereas awareness of personal space is rooted in right inferior parietal regions (supramarginal gyrus, postcentral gyrus)." (Committeri *et al.*, 2007)

sensory awareness and detection; exaggerated increase in defensive behaviors in response to threat detection (Kimble *et al.*, 2014); and attentional biases e.g. repetitive scanning for threatening stimuli (Pineles *et al.*, 2009).

In particular, one study finds “individuals with PTSD exhibit increased BOLD response in subcortical structures”—specifically, in the reciprocally-connected deep-layers of the superior colliculi and dorsal periaqueductal gray (Thome *et al.*, 2014)<sup>15</sup>—providing an “innate alarm system” (Liddell *et al.*, 2005) facilitating defensive-responses including exaggerated-startle, hypervigilance, cowering and escape (Frewen & Steuwe *et al.*, 2015). Over-activation of these regions may decrease the capacity for *theory of mind* and “affiliative interaction” (Thome *et al.*, 2014). Another study of subjects previously exposed to trauma (not necessarily diagnosed with PTSD), found higher reports of hypervigilance covarying with increased saccadic eye-movements during clinical trials (Withers, Terasoff & Stewart, 2013). Therapies influencing activity in these circuits may be clinically beneficial for diminishing physiological hypervigilance; for example, eye-movement desensitization on healthy subjects by (Kapoula *et al.*, 2010) generated a reduction in the number of catch-up saccades during an eye-tracking task to evoke an increase in smooth-pursuit tracking.

Originally developed as “Eye Movement Desensitization” (EMD) by Francine Shapiro (1989), in this procedure subjects “visualize [a] traumatic scene, rehearse [a] negative statement, and follow the investigator’s index finger with their eyes...generating a series of 10-20 voluntary, bilateral, rhythmic saccadic eye movements” (Shapiro, 1996). Such continuous hand movement by the therapist may elicit orienting of smooth-pursuit and saccadic eye movements orchestrated by SC. The effect of EMDR may be to interrupt and reset trains of cognitive trauma by a repeated signal-pattern in the visual field that (for reasons to be determined) sublimates visual-field processing in the cortex to the evolutionarily ancient and corresponding brainstem attention-control module of SC, subsequently dampening the cortical “alerting system” from treating the aberrant signals (memories, thoughts, visualizations) as a threat. This model has broadened to include methods of *alternating bilateral stimulation* like alternating hand-taps or auditory tones, that would likely involve the auditory-orienting module of the inferior colliculi.

Such orienting responses are also “posited to increase the activation of information processing in EMDR” (Lamprecht & Sack *et al.*, 2004) that may affect the brainstem without conscious awareness by “activat[ing] an attention network based in the superior colliculi that, with the formatting of traumatic memory, immediately involves the mesencephalic defense response areas, the mesodiencephalic

<sup>15</sup> Dorsolateral PAG is reciprocally connected with deeper layers of the superior colliculus (Schenberg *et al.*, 2005).

generators of basic affects, and their ventromedial prefrontal controls...where cognitive interpretation of the exteroceptive information can modify responses" (Zubricky & Das, 2022). Given the parasympathetic actions of both acetylcholine and dopamine (Velasco & Luchsinger, 1998) is "consistent with heart-rate deceleration during vigilance and orienting toward distal stimuli" (Graham & Clifton, 1968; Pevic, 1999), it may follow, by commandeering this mechanism one can induce chemical activation of acetylcholine and dopamine in response to certain trains of eye movements precipitating the parasympathetic feelings that follow from EMDR protocols.

## Comments

In the Hawaiian "*huna*" teachings, one of the eight axioms, *makia*, instructs that "where the attention goes, energy flows." Reflecting on times when suddenly compelled by an automatic urge to turn the eyes and head to then encounter some person or creature staring at you, such events bolster the idea that the directed-attention may act as a carrier-wave of psychophysiological energy capable of real impressions in the superior and inferior colliculi of a recipient. The question is, what makes this possible? Is the attention capable of traveling through the environment in differentiable energy-packets through a medium of fields that can also be registered in other organisms? Evidence suggests maybe.

Scopespection can be characterized by a) the transmission of concentrated or sustained attention (staring); and b) by a recipient becoming aware of the source of the stare, which involves reception/detection and automatic motor-orienting of the head and eyes (plus trunk, shoulders) to the source location—as well as autonomic, physiological, emotional, cognitive and behavioral impacts such attention and intentions can induce. While the second point can be contextualized in terms of sensorimotor dynamics in SC, the first point can be verified by neurometric effects in recipients (e.g. McBride *et al.*, 1965; Nichols & Champness, 1971). However, as Atkinson explains, the adjudication of a commensurable model also requires resolving 1) a mechanism or "means by which such a signal might manifest itself, and 2) a means by which organisms may be able to detect such a signal (Atkinson, 2005).

To the *first* point, following the principle of *makia*, the directed-attention may manifest, not as a faculty like vision and hearing, but as an intrinsic or psychophysical force. One line of thought for naturalizing such an interpretation, as indicated in the discussion, may derive from subaudible vocalization and psychoacoustic registry in the inferior colliculus, and co-represented with additional multisensory-maps in the superior colliculus. This speaks to Velman's extramissive interpretation. This requires a field as medium. A more conventional line of reasoning can be provided regarding the autogenic

registry of directed-attention as a built-in commodity of sensorimotor monitoring that manifests in the superadditive milieu of *multisensory facilitation* (computational synergy) stemming from overlapping, retinotopically-aligned multimodal maps in SC, thus providing a wider berth of phenomena than any one modality alone, as well as heightened specificity and sensitivity. The conservation of retinotopic maps across several brain regions suggests a common foundation for autogenic signal processing converging subcortically in SC. These provisions may partly account for an ability to detect when another is staring.

To the *second* point, where Sheldrake nominates externalized (*exogenous*) quantum-like "morphogenetic" perceptual fields, again, this paper offers a contrasting (*endogenous*) neurobiological alternative emphasizing the role of retinotopically-aligned multisensory maps to provide a basic biological substrate for scopespection. Improving upon previous attempts to establish a cortical electrophysiological signature for staring-detection, a neurobiological substrate for scopespection can be identified in the ancient midbrain visual-processing module of the superior colliculus—a sensorimotor conduit involved in the automatic sensorimotor orienting of head-and-eyes to a retinotopically-coordinated source of salient events and prioritized novel activity in the environment; as well as coordinating instinctive defensive behaviors, cognitive and physiological fear-responses—all of which provide an essential benefit to organismic survival supporting neural and behavioral underpinnings for the detection of sustained signals stemming from the directed-attention of another—i.e., scopespection.

These developments also mitigate less-optimistic claims that “positive outcomes of studies of this kind...cannot be explained adequately by the constructs, theories, and worldviews of conventional science” (Braud, 2005); that “there really is no such capacity” as scopesthesia; and that “to the extent there is anything substantive and meaningful in the data at all, it indicates a capacity that is rather more cognitive than sensory-perceptual, namely a belief or reasoning bias” (Atkinson, 2005). Atkinson concludes “the idea of a ‘staring at you’ signal, and Sheldrake’s specific proposal, are far outside the realms of current scientific knowledge” (2005); however, this paper shows SC provides an applicable anatomical and functional profile to account for the neurophenomenological mechanism and psychophysical details for sensory-reception and motor-orientation to the source of being stared-at. This provides a neurobiological basis for further studying mechanisms of the attention. Namely, the “organization of sensory and motor maps, and the close relationship between them, renders this midbrain structure a primary region for addressing a number of fundamental questions in neuroscience. Indeed, the superior colliculus has even been referred to as a microcosm of the brain as a whole” (King, 2004).

To review, SC integrates afferent region/layer-specific *visual, auditory, somatotopic* and *vestibular* signals within a common retinotopic coordinate-frame (topographic map) (King, 2004). These signals correspond with sensory modalities and cognitive features such as salience and priority maps, memory, coordination and visual-scene information deriving from hippocampal spatial fields; grid- and place-cells from the entorhinal cortex; and additionally coordinated memory et al. from cerebellar models. The cumulative effect of these detailed maps bolsters the phenomenological profile for hastening orientation and guiding motor responses toward (*or away-from*) a salient stimulus (Sparks, 1988, 1999; Berson & Stein, 1995); and thus, compounds the possibility that characteristics patently ascribed to scopespection, such as the ability to sense the directed attention of another, can be partially derived from a superadditive epiphenomenon of the autogenic, external monitoring module coordinated in the superior colliculus.

In a larger sense, the topic of scopespection "suggests a profound interconnectedness among the participants. This interconnectedness, in turn, has important implications for our understanding of our full nature, as humans, and of the range and limits of the consciousness mediated influences that we may exert on one another [and] extends our appreciation of the range of our human potentials and the exceptional experiences and abilities of which we are capable" (Braud, 2005). As such, another key area where this could prove to be of significance is in interpersonal synchrony of brain dynamics gaining popularity in studies (e.g., Keyzers & Gazzola, 2009; Hari *et al.*, 2013). Since beginning this paper in 2016, the study of brain-to-brain interactions has gained interest, thus providing another possible evidentiary avenue for contextualizing Sheldrake's notion of local-field potentials surrounding an organism, and how they may be influenced by the concentrated attention and intention of another.

Following the trajectory of this paper, the connectivity profile of SC may be extended to cortical and subcortical regions including *hippocampus, amygdala, medial entorhinal cortex, cerebellum* and *inferior parietal cortex* to elaborate the basis for a multiscale coordination of brain network organization regarding regulatory, exogenous perceptual monitoring that may also lead to further advances in the psychophysical nature of attention, as well as providing further evidence for conditions like blindsight.

Situated on the dorsal posterior aspect of the midbrain, in some ways the superior colliculi really are like eyes in the back of our head.

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