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Stochastic resonance as a proposed neurobiological model for Eye Movement Desensitization and Reprocessing (EMDR) therapy

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A B S T R A C T

EMDR therapy is recommended in several guidelines in the International field of psychological trauma. The dual attention stimuli/alternating bilateral stimulation (DAS/ABS) element of EMDR therapy has no proposed mechanism of action agreed upon, which explains the rapid shifts in cognitions and dysfunctional traumatic memory networks that are central to its observable efficacy. This paper discusses an innate, biological mechanism found in biological systems, including the human nervous system that may explain the efficacy of DAS/ABS. This mechanism is stochastic resonance (SR). SR is observed to make unintelligible, subthreshold signals intelligible and facilitates signal transmission. It provides a potential mechanism for discrimination and the selective focusing of attention, which are important factors in effective psychotherapy for the psychologically traumatised individual. The body/mind complex aims to achieve the functional encoding of memories in the neocortex and a key structural crossroads in this process is the thalamus. Activity in the thalamus is decreased in Post-Traumatic Stress Disorder (PTSD) compared to non-PTSD patients and a form of 'gating' is known to occur at the thalamic level. This 'gating' is adaptive and it is postulated to protect the higher neocortical systems in times of trauma. Although the model is initially somewhat counterintuitive, Stochastic Resonance; a form of random 'noise', can be considered 'helpful randomness' and when present in the thalamus SR can help filter and control sensitivity to incoming signals; helping to discriminate what is communicated. Naturally occurring SR is normally present as a result of descending cortico-thalamic activity, but appears attenuated as a result of exposure to trauma. The view of 'noise' in the current era of cell phones and High Definition is generally negative with science going to significant lengths to clean up signals: i.e. removing noise from them. We do not want white noise in our music or during our cell phone calls. However, some researchers invite us to consider that not all noise is bad and the downward cortico-thalamic 'noise' is an example of this category of 'helpful noise'. This paper will discuss the potential role of SR, as the mechanism by which DAS/ABS generates a random (*stochastic*) signal, facilitating a return to functional memory processing, where there is a lack of naturally occurring noise from the descending cortico-thalamic connections because of exposure to trauma. Modelling the mechanism as SR will facilitate further study into EMDR therapy and this will hopefully encourage perspicacity, where there has previously been derision.

Introduction

Eye Movement Desensitization and Reprocessing (EMDR) therapy is a well-established psychotherapy in the treatment of individuals experiences symptoms associated with Post-Traumatic Stress Disorder (PTSD). It is recommended by a number of bodies as a first line intervention for PTSD [1,2]. In the field of psychotherapy, Eye Movement Desensitization and Reprocessing (EMDR) therapy has the advantage of working with both aspects of the embodied mind. It is not purely psychotherapeutic; neither is it a purely biological method. To encourage such an approach the term 'neurodynamic' was coined by Allan J. Hobson and Jonathan Leonard, who wanted to encourage a 3rd-way for mental health in general and psychiatry in particular, which integrated psychodynamics and neurobiology [3]. EMDR therapy is neurodynamic – in the true sense of their term.

EMDR therapy utilises a psychotherapeutic model, which conceptualises the engagement of an innate information processing system that is described within the Adaptive Information- Processing (AIP) model [4]. The training of EMDR therapy notes that the paradigm models the latest understanding of the neurobiology of psychological trauma [5]. However, it lacks a clear neurobiological foundation [6], which takes into consideration the current body of research pertaining to the neurobiology of trauma. The standard protocol of EMDR therapy consists of an 8-Phase, 3-Pronged Protocol that utilises alternating, bilateral stimulation (ABS), which is applied alongside facilitated information processing that includes dual attention of the inner world

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and the present moment. These procedural steps are administered by the therapist to facilitate the processing of Dysfunctionally Linked Traumatic Memory (DLTM). At this time, the precise mechanism of the ABS, which takes the form of: eye movements, auditory tones and/or tapping, remains unclear and a range of proposed pathways through which the *Dual Attention Stimulation/Bilateral Stimulation* (DAS/ABS) facilitates processing have been offered in the literature [7,8].

Hypothesis

This paper proposes two inter-related, but distinct hypotheses; Firstly, we propose that, just as AIP is thought to be a universal information processing system in the human; DAS/ABS is most likely also working through a similarly ubiquitous process. One that is most likely observable, not only in humans but in nature. Secondly, the paper proposes that the mechanism of action described above, is Stochastic Resonance; a term first employed in the literature in 1980 [9]. In order to evaluate these hypotheses, we will offer a review of the proposed mechanisms of EMDR's DAS/ABS. This will be followed by an explanation of Stochastic Resonance. Finally, we will outline our thinking, which leads us to the conclusion outlined in the second hypothesis.

Review of proposed mechanisms of action of EMDR therapy's DAS/ABS

DAS/ABS in essence requires the traumatised person to focus on both the traumatic event and also the eye movements or other bilateral stimulation. It is hypothesised that this dual attention accelerates the memory processing. Despite the overwhelming evidence of efficacy of EMDR therapy, one of the enduring criticisms of the method is that the underlying processes are ambiguous. As MacCulloch (2006); Page 533 notes, "*A major bar to the further acceptance of EMDR as a treatment and as an inviting research topic stems from the fact that workers still cannot see how eye movements can cause the reported clinical changes and the increasing number of temporally related psycho-physiological phenomena*" [10]. This led to research activity to identify the neurobiological underpinnings of the therapy.

In respect to many of the attempts to understand the mechanism of EMDR therapy's efficacy, the proposed models are built upon the existing knowledge base for classical conditioning. In these models EMDR therapy is examined through a lens that considers it a variant or close relative of Cognitive Behavioural Therapy (CBT). The first paper that explores a possible mechanism of action for DAS/ABS in EMDR therapy [11] suggests that the Orienting Reflex (OR) is engaged by the DAS/ABS through the use of eye movements. This in turn inhibits the emotional disturbance linked with the traumatic memories or DLTM. Further examination of the OR led to the proposal of an extinction model, which suggested that the OR facilitates a reappraisal of, and subsequent change in, the neuronal model of the unconditional stimulus [12]. The same thinking is seen in the paper by MacCulloch and Feldman [13], which submits that DAS/ABS in the form of eye movements (EMs) facilitates a de-arousal of traumatic memories through classical Pavlovian conditioning, by engaging positive visceral components of the investigatory reflex. In other words, the 'novel' signal that DAS/ABS provides engages an innate reflex to investigate, within the safe setting of the therapeutic relationship; resulting in the desensitization of the traumatic memory that has been activated and targeted for processing.

However, the feedback from a substantial amount of clinical hours with patients treated successfully with EMDR therapy, observes that the traumatic flashback images that were once so unavoidable before treatment, become transformed, faded or absent and thus no longer available for conscious access after treatment within EMDR therapy. This suggests that it is through a reconsolidation and processing of the traumatic memory data, rather than the creation of a competing extinction memory that overrides the previously disturbing DLTM. Therefore, given the clinical descriptions by patients, the reconsolidation model is more plausible than an extinction model, which has more to do with a CBT paradigm than the AIP model of EMDR.

Subsequently the literature began to focus more intensely on EMs and their possible effects. Studies proposed that EMs interfered with the vividness of traumatic material in the visuospatial sketchpad of working memory [14] and observed that EMs decreased both memory emotionality and vividness [15]. Work that explored the possible neurobiological means through which a de-arousal of trauma-related affect occurred, was presented based on observations of activity in the subdivisions of the anterior cingulate, part of the brain's limbic system, during hypnotic dissociation [16]. It is hypothesized that the ventral (affective) subdivision of the anterior cingulate gyrus is stimulated by DAS/ABS. This stimulation is hypothesized to result in its subsequent deactivation, which in turn would allow stimulation and activation of the dorsal (cognitive) sub-division of the anterior cingulate [16]. Therefore, once the cognitive sub-division is activated by DAS/ABS this leads to reciprocal inhibition of the anterior cingulate (See Figure 1). Dual-attention and error monitoring are known to activate dorsal regions of the anterior cingulate cortex that mediate metacognitive processing [16]. In other words focusing on two targets and seeking errors stimulates the cognitive area of the Anterior Cingulate Cortex (ACC), which facilitates a person's capacity to think about how they are thinking; otherwise known as metacognition. Neurobiological interest in these brain regions is consistent with later work [17], which suggests that EMs utilise error monitoring to reverse suppression of the dorsal (cognitive) subdivision of the anterior cingulate by lowering activity of the ventral (affective) sub-division. In other words, DAS/ABS switches off the emotional area of the ACC, which then results in a switching on of the thinking area of the ACC. This results in further feedback inhibition of the emotional area, improving higher executive functioning. This is the reciprocal inhibition that Corrigan (2002) described.

It has also been suggested that EMDR de-arouses 'fear memories'. The de-arousing effect of EMs are consistent with the 'reassurance reflex model of EMDR' proposed by MacCulloch and Feldman in two subsequent papers [18,19] and they state that the dearousal is not simply due to distraction.

The reduction of the activity (depotentiation) of limbic synapses is proposed to result from low frequency stimulation and this may be the mechanism through which EMDR therapy quenches or modifies 'fear memory' [20]. Much of this preceding work has focused on specific brain areas and isolated neurobiological systems. However, it is not surprising that an expert in EMDR therapy was the first to suggest that DAS/ABS had an integrative function in the brain and proposed a much more neurodynamic model that was in keeping with the AIP model [21]. The relationship and interconnectivity of the structures within the brain and their functions is characterized by synchronous electrical activity in the Gamma Band frequency (40 Hz). A key effect of psychological trauma upon this interconnectedness is at the level of the Thalamus. Normally, a naturally occurring stochastic (random) signal is usually present in the form of descending cortico-thalamic feedback (Béhuret et al., 2013). However, this innate stochastic signal is blocked in trauma with the down-regulation of the thalamus (Bergmann, 2008). Initially, Bergmann proposed that DAS/ABS reset the septal pacemaker cells enabling the resynchronization of interhemispheric connectivity [21]. Later work by the same author posits a role for activation of the lateral cerebellum, which functions as an association area projecting to the ventro-lateral and central-lateral thalamic nuclei: collections of nerve cells in the brain and spinal cord in which nerve fibres form connections. Activation of these areas is theorized to facilitate repair and integration of somatosensory, memorial, cognitive, frontal lobe and synchronised hemispheric function, which we know are disrupted in PTSD [7]: thereby facilitating a healing response in EMDR therapy.

The ventro-lateral thalamic nucleus is postulated to project to and activate the dorsolateral prefrontal cortex. Bergmann proposed that there is a facilitation of the process that metabolises traumatic memory

into general semantic memory allowing integration with other neocortical networks, resulting from DAS/ABS stimulation [7]. It is postulated that DAS/ABS results in a surge of AcetylCholine (a neurotransmitter) release, facilitating a Rapid Eye Movement (REM)-like state and resulting in a decrease in the strength of hippocampally-mediated episodic memories and amygdaloid-mediated negative affect that are seen in PTSD [22].

REM & Slow Wave Sleep (SWS)

The potential role for sleep and some of its constituent parts within the mechanism of action for EMDR therapy was first brought to the fore by the work of Stickgold [22]. During REM sleep, compared with SWS, there is a much wider activation of more distant associations [23–25] in the Central Nervous System and this may facilitate problem solving. This problem-solving function of sleep activity is in keeping with the Expectation Fulfilment Theory (ExFT) of dreaming outlined by the 'Human Givens' Approach [26]. Dreaming may be thought of as the deepest trance state humans enter and there are three fundamental principles essential to understanding the ExFT of dreaming:

1. Dreams are iconic translations of waking expectations.
2. Only expectations that cause emotional arousals, which are not acted upon in the waking state, become the material for dreams during sleep.
3. Dreaming deactivates the emotional arousal connected to unprocessed material by completing the expectation pattern metaphorically. This ensures the brain starts each new day anew, ready to respond to the demands placed upon it [26].

This process of a neural accessing of wider associations, is characteristic of REM memory processing and of EMDR therapy, but it is not seen in exposure therapy, which focuses on the trauma memory. This is a key differentiation between the psychotherapy methods currently advocated in the treatment of traumatic memories. The wider interconnectedness of brain regions draws in maximal neurodynamic resources, thereby facilitating information processing. Integration within the brain has been the focus of the latest research in this area, and it proposes that EMDR therapy enables the integration of dissociated aspects of traumatic memories, resulting in a decrease in the hyperarousal symptoms we see in PTSD [27]. Knipe summarises the research into the effects of DAS/ABS differently to that noted above, listing the following consequences of the application of DAS/ABS [8]:

1. EMs generate an increase in the vividness of episodic memory retrieval and expansion of association networks [28] following thirty seconds of horizontal saccadic eye movements (but not smooth pursuit or vertical eye movements).
2. EMs during EMDR therapy was observed to activate cholinergic and inhibit sympathetic systems. The pattern of activity has similarities with the configuration observed during REM-sleep [29]. An increase in parasympathetic tone follows EMDR therapy and it is speculated that this would not be solely limited to EMDR therapy, but may also be seen in CBT [30]. Another study showed distinct changes during EMDR therapy for a range of autonomic measures, which included respiratory rate, heart rate, systolic blood pressure (this was observed to increase during early sets, but invariably declined during abreactions, and decreased overall), fingertip skin temperature and the galvanic skin response: all consistently showed a clear "relaxation response". Therefore it was appropriately proposed that EMDR therapy facilitates desensitization by reciprocal inhibition, through the pairing of emotional distress with an unlearned or "compelled" relaxation response [31].
3. EMs (and to a lesser degree alternating tones) were found to reduce the mental avoidance of disturbing material by 'taxing' working memory, while also decreasing the 'emotionality' of the targeted memory network [32]. This built on earlier work that supported a working memory account of EMDR therapy, which found that DAS/ABS in the form of alternating beeps was inferior to eye movements in reducing the emotionality of negative memories [33,34].
4. EMs result in activation of the parasympathetic elements of the OR [13,30].
5. EMs resulted in a decrease in inter-hemispheric gamma electroencephalogram coherence in the frontal areas leading to a reduction in traumatic memory intrusions [35].
6. An increase in the capacity for 'distancing and noticing' with a significant reduction in distress for EM at post-treatment and at follow-up [36]. The effects of the EM element of EMDR therapy were reported as different from other exposure-based therapies [37,38].
7. The facilitation of slow thinking that could result in an increased capacity for an objective assessment [39]. Imagine two people and one is saying something that is blatantly incorrect. The other one might say, "Stop for a moment and think about what you just said." The slowing down aspect of ABS is useful not only in resolving the distortion of posttraumatic disturbance (being afraid when there is no risk) but is also as helpful in realizing the short-sightedness of a psychological defence (such as getting an avoidance urge) [40].

All of the above effects of DAS/ABS in general and EMs in particular are hypothesized to enhance Adaptive Information Processing and facilitate adaptive resolution of a 'trauma memory' [8]. The leitmotif of efficacy as a return to an integrated, functional connection between the both sides of the brain seems fundamental to the efficacy of EMDR therapy. It is logical therefore to search for a ubiquitous mechanism in nature that could facilitate such interconnectivity. Stochastic Resonance is thought to be an excellent candidate for this neurobiological mechanism and as such it deserves further exploration.

Pagani, Amann, Landin-Romero & Carletto [40] have recently focused upon plausible mechanisms within Slow Wave Sleep (SWS) as well as the electrophysiological phenomena of Thalamic Spindles [41], as helping to explain the efficacy and function of ABS of EMDR therapy. They observe that SWS contains delta waves, similar to those observed during the application of ABS in EMDR therapy sessions. SWS is proposed to have a role in memory consolidation and the reorganization of distant functional networks, which would be consistent with the AIP model of EMDR therapy: one of information processing and integration [4]. During the application of ABS in EMDR therapy, cortical firing shifts from limbic regions to those with cognitive valence. This is consistent with what we observe as clinicians applying EMDR therapy, where the initial emotionally overwhelming trauma memory decreases in terms of affect, with an increase in cognitive attributions and metacognition being manifest in the functionally processed memory network that results. During functional memory processing a combined episodic and emotional memory is replayed in the memory-editing matrix of the hippocampal-amygdalar complex; as well as in the neocortex during the first stage of SWS [40]. Concordant with the current theories of AIP and MacLean's Tri-brain model, SWS appears to present an optimal environment for the transfer of edited memories from hippocampus to neocortex; as well as stimulating integration of these into neocortical neuronal networks. Essentially this is the shift we aim for in EMDR therapy; from a Dysfunctionally Linked Traumatic Memory (DLTM) to functional integrated memory networks. In SWS, global synaptic weakening, along with slow consolidation of information is observed and relevant memory circuits are reactivated and long-term potentiation is induced. If we reduce EMDR therapy processes to their most simplified we are essentially activating a memory network, which renders it vulnerable to change; we help the person change it in an adaptive way and then facilitate long term potentiation of a healthy memory network. These memory processing functions characteristic of SWS may go some way to explain the speed of processing that we observe in EMDR therapy. SWS is occurring 3–5 times across any given

night of sleep, compared to the ABS of EMDR therapy in Phases 3–7, which is applied some 25–30 times in EMDR reprocessing. It necessarily follows therefore that an EMDR reprocessing session provides the milieu for the faster processing of material. Memories aroused during EMDR therapy are continuously reactivated, replayed and encoded into existing memory networks, with a reduction of over-potentiation of amygdalar synapses occurring in real-time.

The development of functional cortico-amygdala circuitry is the foundation of mature emotional processing and regulation [42]. The development of a functioning relationship between the amygdalar portion of the memory-editing matrix of the hippocampal-amygdalar complex and the ACC can be helpfully understood to play an important role in mature emotional processing. Positive associations between age and Amygdala-ACC connectivity in anxious youth and young adults is posited to be indicative of a failure to establish early bottom-up connections in childhood and/or less top-down regulation of the amygdala as these individuals matured into adulthood [42]. Furthermore, if we consider that a combination of the deactivation of cortical synapses and hippocampal memories favors transfer of information back to neocortex that is followed by further consolidation in REM, we see a system of emotional and memorial processing involving the decrease of emotionality and the increase of cognitive valence. In this way the proposed effects of SR on the ACC concurs with the work on SWS and thalamic spindles by Pagani, Corletto and others [40,41].

Stochastic resonance?

SR is a phenomenon where a signal that is too weak to be picked up by a sensor, is boosted by the addition of random noise. Thus the original signal, rather than being drowned out by the additional input, is detected. In physics, resonance is defined as the reinforcement or prolongation of sound by the synchronous vibration of a neighboring object. If one of two tuning forks that are pitched at the same resonant frequency is struck, the other will begin to vibrate, as a result of resonance.

SR as a mechanism for EMDR therapy

The phenomenon of SR is observed widely throughout nature in biological, physical and electromagnetic systems. Several organisms, including humans, exhibit SR in their tissues with the first observed SR phenomenon being described in the visual neurones of cats [43]. In humans SR is observed in muscle spindles and has a demonstrable behavioral impact in the human balance system, which is where this author first encountered it. However, SR has not been previously defined or explored in relation to the neurobiology of EMDR in general and for the DAS/ABS elements of the EMDR methodology in particular. Further examples of helpful noise in humans are described: in the hippocampal CA3-CA1 model, where SR is proposed as a mechanism through which memories are recalled [44] and in Attention Deficit Hyperactivity Disorder (ADHD) moderate noise induces SR and is observed to improve cognitive performance [45]. Another example where a stochastic signal can be externally input into the nervous system, demonstrating benefit is with a randomly vibrating gel insole, which improves balance in humans [46]. The research team that developed these stochastic noise-based devices demonstrated that their randomly vibrating insoles could ameliorate age-related impairments in balance control: another example of ‘helpful noise’ that potentially operates through SR [46]. SR is therefore a plausible innate mechanism at work in the nervous system, which may explain the efficacy and importance of the stochastic signal that DAS/ABS provides in the procedural steps of the EMDR method of psychotherapy. In the case of EMDR therapy, we propose that it is the DAS/ABS elements that provide helpful noise within the neural system where processing and interconnectedness is impaired as a sequelae of psychological trauma.

SR and the neurobiological understanding of how mental health pathology arises in trauma

We understand from neuroimaging studies that the thalamus is a vital brain structure in the integration of perceptual, somatosensory, memorial, and cognitive processes [47]. This function is referred to as *thalamo-cortical-temporal binding*; where data is normally metabolised into a functional memory network in the neocortex [7]. In the thalamo-cortico-temporal binding model we propose that a traumatic memory has a sub-threshold signal, which of need of assistance before thalamo-cortical-temporal binding can happen. Normally the innate stochastic feedback from the descending cortico-thalamic pathways facilitates processing [48] and explains how the sub-threshold signal in PTSD patients can be boosted at thalamic level through SR. However, in trauma this descending cortico-thalamic feedback is not available to the system and processing is effectively blocked. This failure within the innate information processing system, caused by trauma, is consistent neurobiologically with what EMDR therapy postulates in the AIP model [49].

SR and the prediction of successful clinical outcomes

It is clear from the current body of neurobiological literature for trauma that increased thalamic activity is an important component in the treatment of PTSD. Given that the activity in the thalamo-cortical tracts is decreased in PTSD compared to non-PTSD controls [7] and that SR results in an increase in the activity of this brain area, SR becomes a plausible candidate for the efficacy of DAS/ABS in EMDR therapy. SR explains how a stochastic signal facilitates the synchronisation of neuronal oscillation and coherence in the brain, which is established by activity in the Gamma-band wave frequency of 40 Hz, which DAS/ABS also generates [7,50]. In other words, the boosting that occurs for the signal allows it to be sensed and communicated onward, through the thalamus to the limbic and neocortical areas facilitated by DAS/ABS, which create the AIP equivalent of 'white noise' at the thalamic level. In situations, both age-related and within brain disorders that have memory deficits that are linked to abnormal functioning in the mesolimbic region, this ‘white noise’ may facilitate learning by restoring functioning in the mesolimbic system [51].

Stochastic resonance and thalamic gating

Sensory information is relayed to the cerebral cortex through the thalamus, which functions as the primary gateway for all sensory input signals on their way to the neocortex. Béhuret created a realistic hybrid retino-thalamo-cortical pathway by mixing biological cells and simulated circuits to allow detailed study of this neural dynamic [48]. The normally occurring, descending cortico-thalamic feedback is a form of *noise* from the cortex (higher brain centres) to thalamic synapses. This was simulated through the injection of a stochastic (*random*) mixture of excitatory and inhibitory signals to the hybrid pathway model. The analysis of the impact of the simulated cortico-thalamic feedback on the overall efficiency of signal transfer highlighted a previously unidentified control mechanism that functions at the thalamic level. This control mechanism was believed to result from the collective resonance of all thalamic relay neurons. The study reported that the efficiency with which signals are transmitted, increases when the level of correlation across thalamic cells decreases [48]. This suggests that the transfer efficiency of relay cells could be selectively amplified when they become simultaneously desynchronized by the cortical feedback. In other words, when the relay cells are not in synchronous activity because of feedback from the higher centres they become better able to communicate. When contemplating how this may function *in vivo* in the human brain, it appears plausible that a mechanism of regulation that is functioning at the thalamic level could potentially, direct the focus of perception to specific thalamic subassemblies. This would mean that

the incoming communication to the cortex could be selected according to the descending influence of the cortical signal [45]. This is crucial, as not only is stochastic noise facilitating the transmission of signal, it may also have a role in the brain's capacity to focus on certain inputs; while ignoring others.

DAS/ABS induces a stochastic signal that is naturally present in the thalamo-cortical system [45] as descending cortico-thalamic feedback. In psychological trauma this stochastic signal in the thalamo-cortical system allows sensing and transmission of an incoming signal to occur by SR [52]. DAS/ABS is observed to result in the activation of the ventrolateral and central-lateral thalamic nuclei. The activation of the ventrolateral nucleus crucially facilitates the activation of the dorsolateral prefrontal cortex, which is known to be disrupted in PTSD [7]. Bergmann further unpacks for us the importance of this area of the brain as follows:

> "This dorsolateral prefrontal part of the brain brings a more analytic and appropriate response to emotional impulses, modulating the amygdala and other limbic areas (LeDoux, 1986). The presence of circuits noted above connecting the amygdala to the prefrontal lobes implies that the signals of emotion, anxiety, anger, and terror generated in the amygdala can cause decreased activation in the dorsolateral area, sabotaging the ability of the prefrontal lobe to maintain working memory and homeostasis (Selemon, Goldmanrakic, & Tamminga, 1995)." [7]

Essentially this is a shift from disconnection to a functionally interconnected state of these important brain areas, which is clinically characterized by a rapid shift from dysfunction to function. The fact that this is an electrochemical shift in signal management and not primarily a structural change in brain tissue helps to explain the speed of change that is observed in patients treated with EMDR therapy [4]. These observations show how the DAS/ABS of EMDR therapy brings online and connects areas of the brain, which are vital for the healthy processing of information; impaired in PTSD. DAS/ABS thus facilitates the repair and integration of somatosensory, memorial, cognitive, and synchronized hemispheric functions. This synchronization of neuronal oscillation occurs at the 40 Hz (*Gamma band*) frequency of oscillation in the thalamo-cortical system [48]. All neuronal activity is linked with electrical charges in some manner and Bergmann observes that not only does this represent communication between nerve cells, it is as Llinás states, "*…the electrical glue that allows the brain to organize itself functionally*." [53]; Page 10. The nature of the neural synchrony represents a pattern of electrical interconnectedness of the brain's neuronal systems, which operates at the 40-Hz frequency (the gamma wave band) and this is thought to be the mechanism through which SR operates [52]. The importance of this frequency is underlined by the observation that the thalamo-cortical system has an intrinsic 40-Hz oscillatory activity, which serves to mediate global temporal mapping by scanning for, targeting, and synchronizing the activity of the various neuronal assemblies [7]. In this way a healthy memory that represents successfully 'metabolized' data is stored as a coherent 'melody' of neuronal activity in the brain that oscillates at 40-Hz. We posit that SR facilitates this process. If SR is successfully induced in the thalamus through DAS/ABS we propose that there will be observable increased activity in this area; resulting in a clinically significant response to the DAS/ABS of EMDR therapy.

In regards to the proposed mechanism of SR, if an incoming signal is sufficient to induce interconnectivity through SR, does the bilaterality of the DAS/ABS signal induce SR more than a non-alternating stimulus? This is a pertinent question. Béhuret observed in an animal model that level 6 cortical neurons, which project to the thalamus, had a greater response to whisker deflections when the motor cortex was focally enhanced [48]. This cortico-thalamic feedback exemplifies a stochastic (random) signal that facilitates signal filtering and transmission at the level of the thalamus [48,52]. Activity in level 6 of the cortex may thus influence cortical sensory responses indirectly through cortico-thalamic feedback projections [48]. This adds credence to the thalamo-cortico-temporal binding model championed amongst EMDR therapy researchers by Bergmann [55].

If we include consideration of the earlier models, which suggest a role for the OR in the efficacy of EMDR [11–13,30], the Orienting Response will result in an increased cortico-thalamic signal [48]. This is not just true for input from the motor cortex. In the 'six-stage valence-code processing model' of Vogt [56], signal transition through the cingulate from posterior to anterior results in orienting to any stimulus. This overt or covert orienting allows the brain to make an assessment in respect to memories, self-significance, motor impulse requirement. At the level of the Anterior Cingulate Cortex, autonomic nervous system outputs [54] all of these cingulate areas have extensive connections with the thalamus, especially the intralaminar and midline nuclei. Accordingly, DAS/ABS is therefore potentially capable of triggering cingulate activity throughout its length *via* the OR to visual, oculomotor, tactile or auditory inputs [57]. This would explain the efficacy of the various forms of DAS/ABS currently utilized in EMDR therapy, which is reported by clinicians.

The visual system shows dense and continuous feedback as a result of a cortical function that is devoted to predicting future sensory inputs. It is thought that this cortico-thalamic feedback modulates thalamic activity and it may be doing so through SR. As a patient is asked to follow the DAS/ABS stimulus, the cortical system, which predicts future sensory input, will be active. In other words, it is believed that DAS/ABS switches on the system in the higher, more advanced brain centres that predict the future trajectory of behaviours. As attention typically amplifies neuronal responses evoked by task-relevant stimuli, while attenuating responses to irrelevant distractors [45], it seems likely that the bilaterality of the DAS/ABS would amplify the SR effect more than a constant, non-alternating stimulus. This is what appears to have been observed by Herkt et al. [58] when they compared 3 groups: bilateral alternating stimulation in the form of auditory tones, bilateral simultaneous auditory tones and no additional stimulation. Their results show the effects for alternating ABS was greater than for simultaneous ABS, which was in turn greater than no additional stimulation [58].

This increased thalamic activity facilitates the focus, repair and integration of somatosensory, memorial, cognitive, and synchronized hemispheric functions that in turn potentiate rapid shifts from a dysfunctional memory network (DLTM) to an integrated functional memory. This type of rapid shift is indeed what we observe in a client successfully treated with EMDR therapy. SR is known to be a mechanism by which 'helpful noise' operates in human neural tissues and the tissues of other organisms. DAS/ABS introduces a stochastic signal, which replaces the normally occurring stochastic signal of descending cortico-thalamic feedback, thereby facilitating gating and communication at the thalamic level. Therefore, we propose that SR reasonably explains the efficacy of the DAS/ABS elements of the procedural steps of the EMDR therapy method. We argue that a stochastic signal in the form of DAS/ABS facilitates the focusing and processing of the unprocessed signal related to a DLTM. Just as EMDR clinicians teach that AIP is an innate system, we can now also propose an innate model for the efficacy of the DAS/ABS of EMDR therapy: the innate biological phenomenon of SR. This innate phenomenon of SR operates in the human neurological system to facilitate the filtering, focusing and processing of information in the brain. Hopefully, by accepting SR as the integrating, neurodynamic mechanism through which DAS/ABS metabolizes trauma memories in EMDR, we will encourage further research and a wider acceptance of this effective psychotherapy.

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Appendix A. Supplementary data

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