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Alterations in autonomic tone during trauma exposure using eye movement desensitization and reprocessing (EMDR)—Results of a preliminary investigation

Martin Sack [a,*], Wolfgang Lempa [b], Adrian Steinmetz [b], Friedhelm Lamprecht [b], Arne Hofmann [c]

[a] *Technical University Munich, Klinikum rechts der Isar, Department of Psychosomatic Medicine, Langerstrasse 3, 81675 München, Germany*
[b] *Hannover Medical School, Department of Psychosomatic Medicine, Carl-Neuberg-Strasse 1, 30625 Hannover, Germany*
[c] *University of Cologne, Department of Psychosomatic Medicine, Kerpenerstr. 62, 50937 Köln, Germany*

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Abstract

EMDR combines stimuli that evoke divided attention – e.g. eye movements – with exposure to traumatic memories. Our objective was to investigate psycho-physiological correlates of EMDR during treatment sessions. A total of 55 treatment sessions from 10 patients with PTSD was monitored applying impedance cardiography. Onset of every stimulation/exposure period ($n = 811$) was marked and effects within and across stimulation sets on heart rate (HR), heart rate variability (HRV), pre-ejection period (PEP) and respiration rate were examined. At stimulation onsets a sharp increase of HRV and a significant decrease of HR was noticed indicating de-arousal. During ongoing stimulation, PEP and HRV decreased significantly while respiration rate significantly increased, indicating stress-related arousal. However, across entire sessions a significant decrease of psycho-physiological activity was noticed, evidenced by progressively decreasing HR and increasing HRV. These findings suggest that EMDR is associated with patterns of autonomic activity associated with substantial psycho-physiological de-arousal over time.

Keywords: Post-traumatic stress disorder; EMDR; Psychophysiology; Impedance cardiography

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1. Introduction

Eye movement desensitization and reprocessing (EMDR) is an established therapeutic approach for the treatment of posttraumatic stress disorder guided by an information processing model (Shapiro & Maxfield, 2002). EMDR incorporates imaginal exposure under conditions of divided attention while attending to some form of oscillatory stimulation. Stimulation is typically provided by the therapist moving a hand from side to side to induce eye movements. The patient follows the moving hand of the therapist with his or her eyes, simultaneously focusing on an inner representation of the traumatic event. Sets of dual attention stimulation are repeated until distress is reduced. Clinical efficacy in the treatment of post-traumatic stress disorder (PTSD) has been demonstrated in several controlled studies (Bradley, Greene, Russ, Dutra, & Westen, 2005; Servan-Schreiber, Schooler, Dew, Carter, & Bartone, 2006; Van Etten & Taylor, 1998; van der Kolk et al., 2007); consequently, EMDR has been recommended as

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* Corresponding author. Tel.: +49 89 4140 4312; fax: +49 89 4140 4845.
E-mail address: m.sack@tum.de (M. Sack).

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an effective treatment for PTSD (American Psychiatric Association, 2004; CREST, 2003; Foa, Keane, & Friedman, 2000).

The need for dual attention stimuli to achieve treatment efficacy during EMDR is currently object of a controversial debate (Pitman et al., 1996a; Rogers & Silver, 2002). Inconsistent results from 'dismantling studies' investigating differential effects of dual attention stimuli versus control conditions raise the question of whether eye movements are critical to the effects of EMDR. However, recent neuropsychological studies have shown that EMDR-like eye movements decrease the vividness of emotionally laden images and their related affects (Barrowcliff, Gray, MacCulloch, Freeman, & MacCulloch, 2003; van den Hout, Muris, Salemink, & Kindt, 2001), and enhance the retrieval of episodic memory (Christman, Garvey, Propper, & Phaneuf, 2003).

Successful desensitization of traumatic memory is thought to depend on both an activation of fear as well as on a habituation to psychological and psycho-physiological arousal during treatment sessions (Jaycox, Foa, & Morral, 1998; Pitman et al., 1996b). While EMDR incorporates exposure to the traumatic memory, some essential principles of exposure techniques are violated by employing a 'distracter' (e.g. the moving hand), interruption of attention, lack of sustained arousal, and lack of 'avoidance prevention' through the use of association (Rothbaum, Astin, & Marsteller, 2005). Therefore, more likely than exposure and habituation, counter conditioning through reciprocal inhibition (Wolpe, 1958) could be regarded as a potentially important treatment factor in EMDR. Desensitization might be facilitated by employing a non-frightening stimulus and distraction through the induction of eye movements or other forms of dual attention stimulation such as kinesthetic or auditive stimuli in combination with short-term periods of exposure. Furthermore, it has been hypothesized that application of repetitive stimuli might elicit a relaxation response either through the mechanism of orienting response (Armstrong & Vaughan, 1996; MacCulloch & Feldman, 1996; Stickgold, 2002) or due to a dearousing effect of the stimulation.

Orienting responses (OR) are a reactions to changes in the environment involving allignment of attention with a source of sensory signals. OR provoke investigatory activity in executive attention networks which are thought to be involved in self-regulation of positive and negative affect (Posner & Rothbart, 2007). OR are known to activate cholinergic pathways of neurotransmission as well as early gene expression (c-fos) in hippocampal structures (Sokolov, Nezlina, Polyanskii, & Evtikhin, 2002). Typical psycho-physiological concomittants of OR are spontaneous and short-term (fewer than 10 s) reactions characterized by increased parasympathetic tone and decreased heart rate, as well as by a lowering of sensory gate levels (Obrist, 1981). Based on this mechanism, application of dual attention stimuli during EMDR may induce a state of decreased psycho-physiological arousal while simultaneously promoting focusing on the traumatic memory.

In a review paper on possible neurobiological mechanism of EMDR, Stickgold (2002) suggested that eye movements or other forms of repetitive stimulation might facilitate contextual integration of traumatic memory in a process similar to information processing during 'Rapid Eye Movement' – sleep (REM-sleep). Repetitive reorienting of attention demanded by the alternating stimulation might activate brain pathways of orienting which might decrease adrenergic drive and shift the brain into a REM-sleep like memory processing mode (Nelson, McCarley, & Hobson, 1983).

In line with these theoretical assumptions, lower levels of electrodermal arousal were identified in healthy subjects receiving eye movements compared to a control condition (Barrowcliff et al., 2003; Barrowcliff, Gray, Freeman, & MacCulloch, 2004). Eye movements also were followed by a significant reduction on measures of memory vividness and emotional valence (Barrowcliff et al., 2004; Lee & Drummond, in press). Other authors reported on psycho-physiological de-arousal during the time course of EMDR treatment sessions (Montgomery & Ayllon, 1994; Wilson, Silver, Covi, & Foster, 1996). In a recently published study (Elofsson, von Scheele, Theorell, & Sondergaard, in press) eye movements during EMDR were shown to activate the cholinergic (parasympathetic) system and to inhibit sympathetic regulation. Following the authors conclusion, the observed psycho-physiological reaction patterns in the study from Elofsson et al. (in press) could not be completely explained as an orienting response.

Together, the cited empirical findings give support to a dearousal model of EMDR. However, there is still uncertainity of whether dual attention stimulation during EMDR would lead to repeated and continued orienting responses or to a single orienting response at the beginning of the set of eye movements. Our study aims to investigate psycho-physiological effects of dual attention stimulation by registering beat-to-beat changes of heart rate and autonomic tone in a naturalistic setting during EMDR treatment.

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We hypothesized that a comparison of psycho-physiological variables at the beginning and end of treatment sessions will show a significant within-session de-arousal. Furthermore, we surmised that the psycho-physiological patterns of an orienting response would be seen at the beginning of dual attention stimulation, including a decrease in heart rate and an increase in parasympathetic tone.

2. Methods

2.1. Subjects

Participants in this study were 10 patients (nine women, one man) of Caucasian ethnic background, who inquired about possible treatment for trauma-related psychological problems at a specialized trauma clinic. All patients suffered from single traumatization and fulfilled diagnostic criteria for PTSD as assessed by the German version of the PTSD module of the Structured Clinical Interview for DSM-IV (Wittchen, Zaudig, & Fydrich, 1997). Four patients were victims of assault violence, three patients survived accidents, two female patients were victims of rape and one patient suffered from awareness during anesthesia. Mean current age was 35.3 years (range 26–47 years). Mean age at the time of trauma was 21.7 years (range 6–42 years) with a mean time elapsing since the trauma of 11.6 years (range 1–25 years). Following a detailed clinical interview, the employment of EMDR was proposed. After receiving information about the aims of the study, all participants gave their written consent. The ethics committee of Hannover Medical School approved the study protocol.

EMDR treatment strictly followed the protocol suggested by Shapiro (1995) and included all eight phases described in her book. Two authors of the study (M.S. and W.L.) – both trained and having more than 7 years clinical experience administering EMDR – carried out the treatment. Duration of therapy followed each patient's individual needs and ranged between 3 and 10 sessions, resulting in a total of 55 sessions.

2.2. Psycho-physiological assessment

Electrocardiogram (ECG) and impedance cardiogram (ICG) were recorded via the Ambulatory Monitoring System (AMS; Vrije Universiteit, Department of Psychophysiology, Amsterdam, Netherlands), with six disposable Ag/AgCL electrodes (Cleartrace, Conmed Corp., New York) placed on the thorax (De Geus, Willemsen, Klaver, & van Doornen, 1995). Reliability and validity of the VU-AMS device have been reported elsewhere (Willemsen, De Geus, Klaver, van Doornen, & Carroll, 1996). At the beginning of each treatment session, placement of the electrodes was followed by an acclimation time of 5 min. Data acquisition then took place throughout the whole session.

Indices of sympathetic and parasympathetic drives were obtained by analysis of ECG and ICG signals. Changes in pre-ejection period (PEP) – the interval in the electrocardiogram between the onset of the QRS complex and cardiac ejection – were used to index changes in cardiac sympathetic drive, and a root mean square of successive differences of adjacent inter-beat intervals (RMSSD) reflecting heart rate variability was used to index changes in cardiac vagal tone. RMSSD correlates well with frequency domain measures of high-frequency heart rate variability and is influenced by cardiac vagal tone as pharmacological blockade studies have shown (Cacioppo et al., 1994).

To measure PEP, the first derivate of the thoracic impedance signal (dZ/dt) was sampled at 250 Hz around each R wave and off-line ensemble averaged over 5 s. The B-point – a notch and upstroke in the impedance signal reflecting opening of the aortic valve – was manually determined for each ensemble averaged segment, and PEP values were determined by adding a fixed Q-to-R interval of 48 ms to the R–B interval time. A times series of inter-beat intervals (IBI) was derived from the R-peak time series (sample rate 1000 Hz) for every heartbeat. Data were controlled for artifacts, such as premature heartbeats, followed by a correction when necessary (in one case 4–6 artifacts had to be corrected per session). RMSSD was calculated for every heartbeat from the five preceding and five following inter-beat intervals. Respiratory frequency values were estimated from the band-pass filtered thoracic impedance.

2.3. Instruments

The Impact of Event Scale (IES) (Horowitz, Wilner, & Alvarez, 1979) is a widely used 15 item self-report questionnaire evaluating experiences of avoidance and intrusion which attempts to reflect the intensity of posttraumatic stress reactions. Horowitz et al. reported split-half reliability for the total scale to be .86 and acceptable internal consistency of the subscales (alpha of .78 and .80, respectively). We used the authorized German version of the IES (Ferring & Fillipp, 1994).

The German version of the PTSD module (Wittchen et al., 1997) of the Structured Clinical Interview for DSM-IV (First, Spitzer, Gibbon, & Williams, 1996) was

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used to assess diagnostic criteria for PTSD before including participants into the study. All interviews were conducted by a trained clinician (M.S.) with more than 8 years of experience in interview diagnostic. Diagnostic reliability was not assessed.

2.4. Data analysis

Pre- and post-changes in psychometric variables were examined using paired samples *T*-test (two-tailed). Psycho-physiological changes during the course of EMDR sessions were explored by comparing during-stimulation (0–60 s) periods for the first two stimulation sets with the last two sets, applying a two-tailed paired samples *T*-test. For a hypothesis-directed comparison of psycho-physiological changes during stimulation, the following measurement periods were defined: (A): final 30 s prior to stimulation (baseline), (B): first 10 s during stimulation, the time frame of expected orienting responses (Gianaros & Quigley, 2001), (C): 10–30 s during ongoing stimulation and (D): 30–60 s during ongoing stimulation. Statistical differences were examined by analysis of variance (ANOVA) for repeated measures, analyzing the main effects of time (measurment period A–D). This procedure was followed by a post hoc comparison in order to contrast pre-stimulation values (phase A) with phases B–D. Overall significance level was set at $\alpha = 0.05$, Bonferroni correction was applied for post hoc comparison The data were analyzed using SPSS version 10.

3. Results

3.1. Psychometrics and descriptive results

Evaluation of PTSD symptoms via standardized questionnaire reveals a significant reduction of symptoms during the course of treatment (IES-pre: $M = 42.2$, S.D. = 16.2, IES-post: $M = 15.6$, S.D. = 14.7; $t(1,9)$: 14.7, $P < 0.001$).

We were able to include psycho-physiological data from all 55 EMDR treatment sessions into the analysis comprising 811 sets of eye movements. The mean frequency of stimulation periods per session was 14.75 s (S.D. = 3.9), with a mean stimulation duration of 59.05 s (S.D. = 11.96).

3.2. Psycho-physiological changes during treatment sessions

Psycho-physiological changes during treatment sessions1. Statistical comparison of psycho-physiological variables during the first two versus the last two stimulation periods of each session shows a significant decrease of heart rate and a significant increase of RMSSD, indicating psycho-physiological de-arousal during the treatment session. No significant changes of PEP were noticed in within-session comparison. Respiration rate decreased significantly, indicating a lower psycho-physiological arousal at the end of the treatment session (see Table 1).

Table 1
Physiological variables during first two vs. last two stimulation periods per treatment session (first 30 s during stimulation)

	First two stimulation periods		Last two stimulation periods		Statistical comparison	
	Mean	S.D.	Mean	S.D.	$t(1,54)$	*P*
HR (bpm)	77.67	11.09	74.55	8.10	4.44	<.001
RMSSD (ms)	30.22	13.92	33.65	13.86	−3.31	.002
PEP (ms)	93.81	21.12	94.41	19.37	−0.77	.443
RESP (bpm)	16.65	0.39	15.05	0.33	3.89	<.001

HR = heart rate, RMSSD = root mean square of successive differences, PEP = pre-ejection period, RESP = respiration frequency. Paired samples *T*-test (two-tailed).

3.3. Psycho-physiological changes during stimulation

Fig. 1 depicts mean values of the heart rate during the final 30 s prior to stimulation and during 60 s of ongoing dual attention stimulation; differently shaded areas show the division of the measurement periods into the periods A–D for statistical data analysis.

Applying analysis of variance for repeated measures, significant time effects for all psycho-physio-

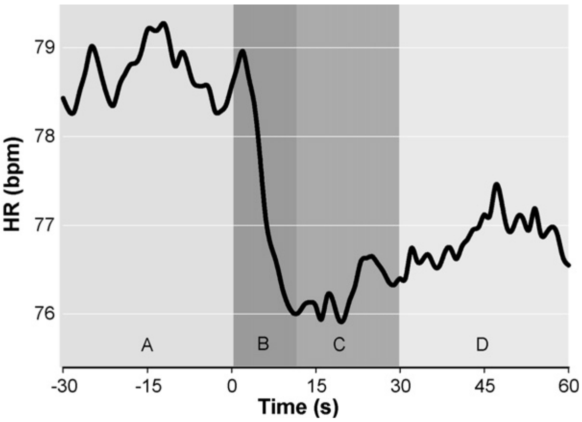

Fig. 1. Mean heart rate pre- and during stimulation. Division into phases A–D for statistical comparison.

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Table 2
Physiological variables pre- and during dual attention stimulation

	Pre-stimulation A: −30 to 0 s		During stimulation B: 0–10 s		C: 10 –30 s		D: 30–60 s		Main effects		Post hoc comparison		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	*F*(3,786)	*P*	A/B	A/C	A/D
HR (bpm)	78.87	10.45	77.86	9.76	76.33	10.31	76.83	10.55	137	<.001	***	***	***
RMSSD (ms)	32.29	19.23	35.73	21.00	30.54	15.91	29.76	16.82	41.4	<.001	***	n.s.	***
PEP (ms)	96.04	20.91	95.74	20.58	95.49	20.58	95.42	20.61	5.2	.023	n.s.	**	n.s.
RESP (bpm)	14.85	2.42	15.26	2.80	15.98	2.98	16.27	3.01	173	<.001	***	***	***

HR = heart rate, RMSSD = root mean square of successive differences, PEP = pre-ejection period, RESP = respiration frequency. Anova repeated measures, post hoc comparison (Bonferroni corrected for multiple testing): n.s. = non significant, $^{**}P < .01$, $^{***}P < .001$.

logical variables were noticed (see Table 2). Post hoc comparison of pre-stimulation values with during-stimulation phases reveals a significant decrease of heart rate during stimulation phases (B–D) when compared to the pre-stimulation period. Compared to pre-stimulation RMSSD, our measure of parasympathetic tone increased significantly during the first ten seconds of stimulation (phase B) and decreased to levels lower than baseline during ongoing stimulation, wherein only the comparison of A versus D reached the level of statistical significance. Significant changes for PEP were only found in a comparison of A versus C in terms of decreased PEP during ongoing stimulation, indicating increased sympathetic tone. Respiration rate increased significantly during stimulation.

4. Discussion

This preliminary study examines changes of psycho-physiological variables during trauma exposure while administering a total of 55 sessions of EMDR to 10 patients with PTSD. Present results show a significant de-arousal in terms of a decrease in heart rate, a decrease in breathing rate, and an increase in parasympathetic tone when the first two and the last two sets of dual attention stimulation per session were compared. These findings indicate a significant within-session habituation of psycho-physiological arousal therefore supporting previous findings (Wilson et al., 1996; Montgomery & Ayllon, 1994) reporting a within-session psycho-physiological habituation during EMDR. Decreases in physiological arousal are known to precede cognitive changes during exposure, and may help to uncouple stimulus and response elements (Nishith, 2002). The within-session psycho-physiological habituation observed here fits into the empirically well-grounded model of fear processing during exposure treatment (Jaycox et al., 1998).

Guided by theoretical assumptions about the potential occurrence of an orienting response at the initial stimulation, levels of autonomic arousal before the beginning of stimulation and during stimulation (following the moving hand of the therapist with the eyes) were compared by defining the following time periods: last 30 s before stimulation begins (A), first 10 s during stimulation (B), the following 20 s of stimulation (C) and second 30–60 during stimulation (D). Post hoc comparison of psycho-physiological variables before stimulation and during stimulation reveals a significant decrease in heart rate during stimulation indicating dearousal. Parasympathetic tone (RMSSD) increased only during the first 10 s of stimulation when compared to the pre-stimulation period. We would attribute the observed time limited increase of parasympathetic tone associated with a decrease of heart rate at the very begin of the stimulation as the psycho-physiological concomittants of an orienting response (Obrist, 1981). In fact, our results indicate that sets of eye movements were followed by a relaxation response with a moderate (approximately 3 bpm, see Fig. 1) drop in heart rate and a simultaneous increase in parasympathetic tone. This psycho-physiological reaction shows a clear association with the onset of dual attention stimulation, with a nearly instantaneous drop of heart rate when stimulation begins. We therefore conclude that redirecting the focus of awareness at the start of dual stimulation may elicit an orienting response with associated psycho-physiological de-arousal.

As dual attention stimulation proceeded further, an opposite pattern of psycho-physiological reactions was noticed. Compared to the pre-stimulation baseline, heart rate increased slightly but stayed on a significantly lower level, while parasympathetic tone decreased and respiration increased significantly. We understand these findings as psycho-physiological correlates of exposure induced anxiety and distress, causing a simultaneous

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decrease of parasympathetic tone and increase in sympathetic tone.

As possible explanation for the observed biphasic psycho-physiological reaction during exposure we assume an overlap of two distinct influences: first, at the very beginning an orienting response dominates the picture characterised by a short-term decrease of heart rate and a sharp enhancement of vagal tone. Second, during ongoing exposure a stress-related increase of psycho-physiological arousal emerges.

While an activation of cardiovascular parameters during recall of traumatic memory is a known prerequisite for during-session habituation (Jaycox et al., 1998), patterns of psycho-physiological dearousal at start or during exposure are not part of the traditional concept of exposure therapy. In a study investigating healthy participants, Kuiken (2001) demonstrated that eye movements facilitate not only attentional orienting but also semantic flexibility in the client's narrative of the traumatic event. The authors hypothesized that eye movements facilitate shifts in the contents of working memory therefore enhancing the chance of associating new and more adaptive information to the dysfunctional traumatic memory. Christman et al. (2003) found that bilateral eye movements enhance the retrieval of episodic memories and other studies investigating healthy subjects showed a reduction in negative effect associated with the application of eye movements (Andrade, Kavanagh, & Baddeley, 1997; Barrowcliff et al., 2004; van den Hout et al., 2001). Taken together these findings point out that dual attention stimulation during exposure might be one potential mechanism of desensitization of negative affect and integration of traumatic memory. We therefore propose an extension of the emotional processing model (Foa & Kozak, 1986), in which short-term psycho-physiological de-arousal initiated by orienting responses may help to facilitate the integration of corrective information about the meaning of feared stimuli and responses. Moreover, it may be that any stimulation which elicits strong orienting responses in the presence of trauma-related anxiety will potentially facilitate desensitization (Armstrong & Vaughan, 1996). However, short-term exposure to highly distressing stimuli in combination with a distraction task that does not induce orienting – if indeed this were the case for following the hand of the therapist during EMDR – should be relatively ineffective and only result in a slight decrease of fear (Foa & Kozak, 1986).

Our study adds empirical support to other reports on patterns of psycho-physiological dearousal during the application of eye movements. Barrowcliff et al. (2003) reported on lower levels of electrodermal arousal when eye movements where applied in healthy subjects. Elofsson et al. (in press) found a decrease in heart rate, skin conductance, an increase in finger temperature and increased parasympathetic tone during eye movements. Similar to our findings, Elofsson et al. (in press) also report on findings not compatible with an orienting response (e.g. an increase in breathing frequency during eye movements). In our opinion, these inconsistent findings might be explained by the occurrence of two concurrent effects: first, a relaxation response associated with dual attention stimulation. Second, a stress response elicited by the exposure to traumatic material.

This preliminary study was designed to investigate psycho-physiological concomittants of dual attention stimulation during real life EMDR treatment sessions. Our study results raise the question whether the reported orienting response patterns of psycho-physiological reaction are caused by the application of dual attention stimulation during exposure and whether they are specifically connected to treatment outcome. Unfortunately, both questions can not be answered from our data. Since we did not include a control group receiving the same treatment except eye movements, a causal relationship between stimulation onset and the observed psycho-physiological dearousal remains unclear. Other treatment-related conditions, such as redirection of the inner focus of attention towards the traumatic memory, might have contributed to the observed psycho-physiological changes. Although the results of experimental studies investigating the effects of eye movements in healthy subjects (Barrowcliff et al., 2003) indicate that dual attention stimulation can cause psycho-physiological changes in patients being treated for PTSD, this can only be ascertained by thorough experimental investigations comparing EMDR to an appropriate control condition. Second, the contribution of psychological changes during EMDR to treatment outcome remains unclear since our study followed a naturalistic design with an individual treatment length ranging from 3 to 10 sessions, and symptom changes from session to session were not assessed. Although we found a clear orienting response pattern of psycho-physiological dearousal at begin of stimulation, our methods leave undecided whether this is result of a single orienting towards the waving hand or whether multiple orienting responses are elicited during stimulaton. To answer this question recording of peripheral psychophysiology might be insufficient; studies investigating central activation (e.g. EEG) are more promising for monitoring possible concomittants of repeated orienting. Another limitation of our study is that gender effects have not been controlled for.

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This study shows the occurrence of orienting response patterns associated with onset of stimulation during 'real life' EMDR treatment sessions. Future research should relate observed psycho-physiological changes to concomitant central nervous system and cognitive processes as well as to pre- and post-sessions measures of PTSD symptoms and treatment progress. Simultaneous monitoring of sympathetic and parasympathetic tone is promising for elucidating mechanisms of exposure treatment.

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