ATTENTIONAL DISSOCIATION IN HYPNOSIS AND NEURAL CONNECTIVITY: Preliminary Evidence from Bilateral Electrodermal Activity

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Abstract: According to recent findings, interhemispheric interactions and information connectivity represent crucial mechanisms used in processing information across various sensory modalities. To study these interactions, the authors measured bilateral electrodermal activity (EDA) in 33 psychiatric outpatients. The results show that, during congruent Stroop stimuli in hypnosis, the patients with higher hypnotizability manifest a decreased level of interhemispheric information transfer measured by pointwise transinformation (PTI) that was calculated from left and right EDA records. These results show that specific shifts of attentional focus during hypnosis are related to changes of interhemispheric interactions that may be reflected in neural connectivity calculated from the bilateral EDA measurement. This attentional shift may cause dissociated attentional control disturbing integrative functions of consciousness and contextual experiences.

Historically the first study concerned with attentional states in hypnosis and electrodermal activity (EDA) was reported by Prince and Peterson (1907), who examined a patient with multiple personality disorder. In this patient, Prince and Peterson found three alternate personalities. When this patient was in the hypnotic state, they used experimental measurement of electrodermal activity during the presentation of specific words related to past experiences of these alternate personalities. In these hypnotic conditions, they found increased EDA amplitude (in the form of galvanic skin response [GSR]) in response to these specific words, although the dominant conscious personality did not remember these past experiences. These findings suggest that EDA is able to reflect unconscious processes and hypnosis may enable one to distinguish emotional responses related to dissociative states in multiple personality disorder.

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Further research of hypnosis using EDA has shown that typical suggestions of relaxation and drowsiness in hypnotic inductions declined skin conductance (Barber & Hahn, 1963; Davis & Kantor, 1935; Estabrooks, 1930) but during active hypnosis the EDA response was similar to normal waking state (Davis & Kantor, 1935). These data suggest that electrodermal responses in hypnosis are not specific for hypnotic conditions but are similar to normal relaxed or waking state (Edmonston, 1968). Although, in principle, EDA in hypnosis reflects a level of relaxation or sympathetic arousal, several data indicate that certain levels of relaxation or arousal could be specific for hypnotic conditions. For example, Wickramasekera, Pope, and Kolm (1996) have found that high hypnotizable persons had increased skin conductance levels (SCLs) following stress stimuli in comparison to low hypnotizable subjects, who had lower SCLs in response to the same stimuli. Similarly, Robinson et al. (2006) examined sympathetic nerve activity with microneurography using implanted electrodes into skin nerves in the hypnotic state and found that hypnotic suggestion increased activity of the sympathetic nervous system in conditions when hypnotic suggestion has been used to experience increased difficulty during experimental tasks, while hypnotic suggestion that decreased difficulty also decreased sympathetic activity. These changes were not found in nonhypnotic subjects.

Also, other studies reported the influence of hypnosis on electrodermal activity, for example, influences of posthypnotic suggestion for enhanced vigilance were found to dramatically increase SCR in military pilots (Barabasz, 1985). Similar results that indicate several specific electrodermal characteristics of hypnosis were also found in research focused on attentional processes of orienting and focusing attention and habituation related to stimulus repetition. These experimental conditions enable attentional redirection that involves modulation of the limbic system, particularly structures of the amygdala and hippocampus (e.g., Pribram and McGuinness, 1975; Gray, 1982). For example, using a standardized tone orienting and habituation paradigm, Gruzelier and Brow (1985) focused on effects of hypnosis on orienting responses to tones in normal and patient volunteers. Results of this study indicate that subjects with high susceptibility to hypnosis have a reduction in orienting and/or faster habituation with hypnosis, whereas low susceptibles showed retarded habituation with hypnosis. The facilitation of habituation with hypnosis was replicated in an experiment designed to compare hypnosis with simulating hypnosis in medium and high hypnotizable subjects (Gruzelier, Allison, & Conway, 1988). Gruzelier et al. found that the habituation was faster with hypnosis in the susceptible subjects, while in simulators the habituation was slower.

These findings seem to be in agreement with influences of the amygdala and hippocampus on EDA (Critchley, 2002) and also with
evidence that the amygdala has main excitatory influences on orienting activity, whereas the inhibitory action of the hippocampus facilitates the habituation of the orienting response with stimulus repetition (Gruzelier & Venables, 1972; Pribram & McGuinness, 1975). Influence of hypnosis on these processes likely could be explained by functional inhibition of the amygdala and activation of the hippocampus (De Benedittis & Sironi, 1988).

Although the above-reviewed data were obtained using both unilateral and bilateral EDA measurements, there are interesting findings related to specific changes in laterality during hypnosis that can be obtained only using bilateral electrodermal activity. These changes related to influences of hypnosis on laterality have been demonstrated in experiments investigating the right hemispheric involvement in hypnosis (Pedersen, 1984). For example, Gruzelier and Brow (1985) reported an experiment focused on bilateral electrodermal orienting and habituation processes and found an asymmetry in the amplitude of orienting responses favoring the right hand in hypnosis in high susceptibles in comparison to low susceptibles.

In addition to these findings, further experiments using bilateral EDA and other electrophysiological measures indicate that the left hemisphere is also specifically involved in hypnosis (Jasiukaitis et al., 1997). Recent evidence suggests that left-hemispheric functions in hypnosis could play a specific role in synthetic capabilities and pre-determined motor programs that may implement right hemispheric activation (Jasiukaitis et al., 1997). These problems with “relateralizing hypnosis” likely indicate that neurophysiological processes during hypnosis could be rather explained by dynamical changes in hemispheric activities and interactions between hemispheres than the specific functional and neuroanatomical localization.

Specifically, a useful condition that enables one to study these dynamical interactions between hemispheres related to processes of selective attention during hypnosis represents Stroop congruent and incongruent tasks. In a typical Stroop task, a subject is required to name the ink color of a written word that may be congruent (e.g., red is printed in red ink) or incongruent (e.g., red is printed in green ink). This process is related to response inhibition, sensory rejection and the Stroop task has also been used as a model of the stress defense reaction in humans (Freysschuss, Hjemdahl, Juhlin-Dannfelt, & Linde, 1988; Hoshikawa & Yamamoto, 1997). The neural interference related to cognitive conflict predominantly occurs in the anterior cingulate cortex (ACC) and structures of the central autonomic network that also includes limbic structures such as the amygdala and hippocampus and elicits autonomic responses that can be assessed using psychophysiological measures (Critchley, 2002; Critchley et al., 2003; Hoshikawa & Yamamoto, 1997). Because, in the Stroop task, the two dimensions of the
stimulus (meaning of the word and color) are competing for limited system capacity during neural interference, performance of the Stroop task may be also used as a measure of attention. This involvement of attention during the Stroop task is particularly suitable for research of the brain dynamics in hypnosis that is also specifically related to attentional processes. For example, Barber (1960) documented that selective attention related to hypnotic suggestions represents a necessary condition for hypnotic behavior.

In later studies, the role of selective attention in hypnotic behavior was also supported by Karlin (1979), who proposed that attentional processes may be critical for understanding of hypnotic behavior. Very intriguing findings indicate that Stroop-like interference can be influenced by hypnosis. For example, Sheehan et al. (1988) tested whether high susceptible subjects, in comparison to low susceptible subjects, would show less Stroop interference under hypnosis than when awake. They found that compared with performance in the waking state, the Stroop effect actually increased under hypnosis, which is particularly evident in the high susceptible subjects. In addition, they found that when provided with an attentional-focusing instruction under hypnosis, high susceptible subjects sharply reduced the Stroop effect, whereas low susceptible subjects decreased it only slightly.

Following these findings, recent studies also confirm that, within specific attentional contexts in hypnosis, the Stroop effect can be significantly reduced or even completely eliminated (Besner, 2001; Melara & Algom, 2003; Raz et al., 2002, 2003, 2005, 2007). These findings are in agreement with traditional views that hypnosis itself is characterized by strongly focused attention, and that hypnotic susceptibility is due to individual differences in the ability to engage in such focused attention (Barber, 1960; Spiegel, 2003; Tellegen & Atkinson, 1974; cf. Jamieson & Sheehan, 2002; Crawford, 1994). These findings suggest that modulation of attention in hypnotic states is coupled to the global changes in subjective experience and markedly influences regulation and monitoring of the body and mental states, experiencing of the self and underlying process of self-representation. Self-representation as a mental structure creating identity and awareness can be defined as a result of interpretation of certain inner states of one’s own body as parts of mental and somatic identity, while other bodily signals are interpreted as perceptions of the external world (Bob, 2008). Alterations in “self-representation” that underlie the changes in subjective experience are linked to great and abrupt changes in patterns of neural activity. This supports the notion that hypnosis, because of significant attentional shifts, leads to a distinct “dissociated state” of consciousness (Metzinger, 2000; Rainville, Duncan, Price, Carrier, & Bushnell, 1997; Rainville, Hofbauer, Bushnell, Duncan, & Price, 2002; Bob, 2008).
Altogether, recent findings indicate that highly hypnotizable persons can better inhibit incoming sensory stimuli through various regulatory influences of the frontal cortex on the limbic system that enable attentional control of the stimuli (Crawford, 1994; Rainville, Hofbauer, Bushnell, Duncan, & Price, 2002; Raz, 2005). In addition, highly hypnotizable persons can better focus and sustain their attention as well as better ignore irrelevant stimuli from the environment (Bob, 2008; Crawford, 1994; Raz, 2008). These findings suggest that highly hypnotizable persons possess stronger attentional filtering abilities than low hypnotizables and that these differences are reflected in underlying brain dynamics such as an interplay between cortical and subcortical structures and interhemispheric interactions (Eccleston & Crombez, 1999; Crawford, 1994; Feldman, 2004; Edmonston & Moscovitz, 1990).

These findings show that, for example, during attentional processing of visual information, interhemispheric interactions become relatively more advantageous in comparison to within-hemisphere processing (Banich, 1998, 2003; Passarotti, Banich, Sood, & Wang, 2002). Further data indicate that interhemispheric interactions may represent a general mechanism that the brain uses across different sensory modalities to increase information-processing efficiency, most likely by splitting the load of processing between the two hemispheres and allowing information to be processed in parallel mode (Banich, 1998; Passarotti et al., 2002). Interhemispheric interactions may dynamically allocate different computations in both hemispheres through mechanisms similar to parallel computers that dynamically distribute information processing (Banich, 1998; Nelson & Bower, 1990). In this context, Banich (2003) proposed that the corpus callosum may play a significant role in processes of selective attention and can modulate attentional capacity.

Experimentally these specific changes in interhemispheric interactions and information flow may be detected using EEG and functional magnetic resonance imaging (fMRI) but also using bilateral electrodermal activity (EDA) may represent a sensitive indicator of interhemispheric interactions, mainly because of limbic modulatory influences on EDA (Bouscein, 1992; Canals et al., 2008; Critchley, 2002; Pulvermuller, 1996). For example, according to recent findings, there is evidence that the limbic system specifically influences and modulates EDA, and reported results show that EDA and levels of activity in the amygdala are significantly correlated (Critchley, 2002; Mangina & Beuzeron-Mangina, 1996). Other reported data also indicate that other bilateral structures may be involved in EDA modulation, for example, the anterior cingulate cortex (ACC), ventromedial and dorsolateral...
prefrontal cortices, parietal lobes, insula, and hippocampus (Critchley, 2002; Mangina & Beuzeron-Mangina, 1996; Phelps et al., 2001).

Recent findings also show that EDA reflects activity of the autonomic nervous system, which is functionally related to emotional arousal and stress (Bob, 2007; Critchley, 2002; Mangina & Beuzeron-Mangina, 1996; Phelps et al., 2001). The EDA typically reflects activity within the sympathetic axis of the autonomic nervous system that is closely linked to emotions, and EDA is widely used as a sensitive index of emotion-related sympathetic activity (Bouscein, 1992; Critchley, 2002; Dawson, Shell, & Filion, 2000; Fowles et al., 1981; Venables & Christie, 1980). This relationship enables one to use unilateral or bilateral EDA as an objective index of emotional behavior or an indicator of conditioning in humans (Critchley, 2002). These findings also show that the amygdala plays a key role in the processing of emotional stimuli, especially fear and other arousing emotions (Hamann, Ely, Hoffman, & Kilts, 2002), and the role of the amygdala in valence and arousal report that it also plays a part in processing biologically relevant and highly arousing stimuli (Adolphs, Russell, & Tranel, 1999; Glascher & Adolphs, 2003; Taylor, Libezron, & Koepepe, 2000). These findings show that the amygdala is involved in EDA responses to motivational stimuli, particularly when these stimuli acquire meaning through learning. EDA is sensitive for measurement of autonomic arousal and can be used to measure emotional processing because of transient EDA alterations by emotional stimuli (Bauer, 1998; Yoshino, Kimura, Yoshida, Takahashi, & Nomura, 2005).

These findings suggest a hypothesis that specific changes in selective attention and interhemispheric interactions during hypnosis could be reflected in left-right information transfer calculated from bilateral electrodermal measurement (in this approach the same like right-left). The hypothesis is in agreement with the data, indicating that interhemispheric interactions may modulate the level of attentional capacity. These data implicate that the increased level of attention that typically occurs in hypnosis could be linked to decreased information transfer and neural connectivity between left and right EDA records. This decreased information transfer might be especially decreased during cognitive tasks focusing attention and, on the other hand, any attentional distraction likely will cause an increase of information transfer and decreased attentional capacity.

In this context, the aim of this study was to compare indices of the left-right information transfer calculated from the bilateral electrodermal activity during hypnotic attentional states influenced by Stroop congruent stimuli focusing attention and to compare it with attentional distraction caused by incongruent Stroop stimuli. According to reported findings, levels of attentional involvement in hypnosis and hypnotizability are closely related (Bob, 2008; Crawford, 1994;
Raz, 2008), which hypothetically may implicate a relationship between information transfer and hypnotizability.

In addition, as a condition, increasing attentional involvement has been used in hypnotic suggestion by inducing hallucination of black–white seeing. This suggestion, inducing strong attentional filtering due to the negative hallucination of colors, could prevent attentional distraction and conflict (between word and color) during incongruent Stroop stimuli. The negative hallucination of colors also may help to distinguish typical effects of hypnosis on attentional functions and related left-right information transfer on the level of the autonomic nervous system, which likely reflects interhemispheric communication due to limbic modulatory influences on EDA.

**METHOD**

**Participants**

For experimental examination of the proposed hypothesis, the EDA recording and nonlinear data analysis were used in 33 psychiatric outpatients (see Table 1) with a diagnosis of anxiety disorder (with comorbid depressive symptoms) \( n = 19 \) and depressive disorder (with comorbid anxiety symptoms) \( n = 14 \) confirmed according to the Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV) criteria (American Psychiatric Association, 1994). Because the hypothesis has no specific prediction regarding participants included in the study, the patients represented a typical sample of outpatients with depression and anxiety treated by hypnosis at the Center for Neuropsychiatric Research of Traumatic Stress.

The patients were also assessed by M.I.N.I. version 5.0.0 (Sheehan et al., 1998). All the patients were in remission and used only low or medium doses of antidepressant or anxiolytic medication. Exclusion criteria were psychotic symptoms, organic illnesses of the central nervous system, epilepsy, mental retardation, and alcohol or drug abuse. The patients were 14 males and 19 females average

**Table 1**

*Patients Included in the Study*

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Anxiety</td>
<td>19</td>
<td>10/9</td>
<td>31.32</td>
<td>—</td>
<td>6</td>
<td>4</td>
<td>7.14</td>
</tr>
<tr>
<td>Depression</td>
<td>14</td>
<td>9/5</td>
<td>34.19</td>
<td>11</td>
<td>—</td>
<td>2</td>
<td>6.08</td>
</tr>
<tr>
<td>All the</td>
<td>33</td>
<td>19/14</td>
<td>32.54</td>
<td>11</td>
<td>6</td>
<td>6</td>
<td>6.69</td>
</tr>
</tbody>
</table>

Note: Hypn. = Hypnosis
age of 32.54 ± 9.23 with predominantly a high school education. Hypnotizability testing has shown that 15 patients from this sample had higher susceptibility to hypnosis according to the Stanford Hypnotic Susceptibility Scale, Form C (SHSS:C > 7) (Weitzenhoffer & Hilgard, 1962). All the participants were right handed according to the Waterloo Handedness Questionnaire (Elias, Bryden, & Bulman-Fleming, 1998). The study was approved by the Charles University ethical committee and all the participants gave written informed consent.

EDA Measurement

EDA was recorded using a bilateral two-channel SAM unit and was processed by software Psylab (Contact Precision Instruments). The SAM unit was connected to a personal computer and a sampling frequency of 1000 Hz was used. The EDA measurements were done in a quiet room with the temperature at about 23°C. The participant sat in a comfortable chair and EDA was measured using two pairs of Ag/AgCl electrodes (8 mm diameter active area). The electrodes were filled with electroconductive paste and attached to the medial phalanges of the index and middle finger of both hands. EDA was recorded during rest, during the congruent and incongruent Stroop tasks, and these three experimental periods were recorded during waking state and during hypnosis. After the recording of the Stroop task in the waking state and a 2-minute long resting period, a hypnotization procedure and hypnotizability assessment using the Stanford Scale of Hypnotic Susceptibility, Form C (SHSS:C) were used (Weitzenhoffer & Hilgard, 1962). Then the same Stroop task was presented during waking hypnosis and then again after hypnotic suggestion inducing black-white seeing (“Now you will see all things in this room only as a black-white image!”). The experimental procedure was followed by a suggestion for relaxation. After a 5-minute long relaxation period, a dehypnotization procedure according to Stanford Scale was performed (Weitzenhoffer & Hilgard, 1962).

Stroop Word-Color Test

In a typical Stroop word-color test (Stroop, 1935), an experimental subject is required to name the ink color that may be congruent (e.g., red is printed in red ink) or incongruent (e.g., red is printed in green ink). Successful incongruent Stroop task performance needs to ignore the meaning of the printed word. This process involves sensitive attentional mechanisms of selection related to response inhibition and sensory rejection that enables one to use the Stroop task as a model of stress-defense reactions (Freyschuss et al., 1988; Hoshikawa & Yamomoto, 1997). The cognitive conflict due to the incongruent stimulus is related to the neural interference that predominantly occurs in the ACC (Bob,
The ACC activity influences other parts of the central autonomic network that includes amygdala, hippocampus, and other limbic structures, which are closely related to autonomic responses that can be measured using psychophysiological techniques (Critchley, 2002; Critchley et al., 2003; Hoshikawa & Yamamoto, 1997).

During EDA recording and administration of the Stroop task, three experimental periods have occurred. The first experimental period was a resting state lasting 100 seconds; the second state was during the congruent Stroop task and included four tables with words (green by green ink, red by red ink, blue by blue ink, yellow by yellow ink); and the third state was during the incongruent Stroop task that included four tables with words (green by red ink, red by green ink, blue by yellow ink, yellow by blue ink). Both Stroop presentations were related to the regularly changing questions of “name the color” and “name the word” with a 20-second pause between the congruent and incongruent Stroop tasks. Tables with the Stroop stimuli (A4, with types size 72 mm) were presented at a distance of about 50 cm. Subjects were required to complete four words with a 5-second pause after each response (and a 20-second pause between the congruent and incongruent Stroop tasks).

Data Analysis

Theoretical and experimental approaches for studying complex dynamical systems are various methods of a time-series analysis. A basic postulate of these methods is that every dynamic system (e.g., the human brain and its functions) is governed and also determined by a certain number of independent variables. Because any real measurement on a system cannot provide information about all its variables due to the high complexity of the system, the main purpose of the time-series analysis is a mathematical approximation and reconstruction of certain variables from signals produced by this underlying multidimensional dynamics, for example, psychophysiological data measured on the system during the time (Kantz & Schreiber, 1997).

Because any observational data may reflect only a few real independent variables of the system, any approximation of the dynamic system behavior may only use a finite number of mathematically reconstructed variables that may enable one to describe the approximate states of a system or the relationships between subsystems. In this context, interactions between subsystems may be measured using methods of mutual interactions and information flow, which may be computed in the “phase space” using measures of pointwise transinformation (PTI).

The PTI was derived from Shannon’s information concept and also takes into account nonlinear dependencies of two observable quantities and can be applied to nonstationary time series (which are typical for various biological signals). It is calculated in the phase space of the
observables from their probability densities (Lambertz, Vandenhouten, Grebe, & Langhorst, 2000; Liang, Ding, & Bressler, 2001). In practice, this calculation is based on empirical point densities in the neighborhood of the reconstructed trajectory and the PTI depends on the selected search radius \( r \); because PTI values are not normalized, negative values also may occur. Increased or decreased PTI values over time provide information about changes in the coupling behavior of the two subsystems with time resolution limited by a sampling rate of a signal (Lambertz et al., 2000).

The defining formula for the \( i \)-th time step is the following:

\[
Y = I(\delta, r, i) = \log_2 \frac{P_{x1x2}(\delta, r)}{P_{x1}(r)P_{x2}(r)},
\]

where the transinformation \( I \) is a function of the relative shift and relative phase space radius \( r \) given for every sample point \( i \). It denotes the probability of finding a point on the reconstructed trajectory within a sphere of radius \( r \) around the \( i \)-th phase space point and refers to the phase spaces of the time series \( x_1 \) and \( x_2 \).

The method was applied to the recorded signals representing the complex couplings of the physiological subsystems (in this case the left and right sides of the EDA). If the signals show marked rhythms, instantaneous frequencies and their shifts are demonstrated by time frequency distributions, and instantaneous phase differences show couplings of oscillating subsystems. These methods are useful for analyzing coupling characteristics of the complex physiological system and enable detailed analyses of the internal dynamic coordination of subsystems. In the data analysis, an approximately 25- to 50-second long left- and right-EDA time series during nonconflicting and conflicting Stroop tasks was processed by nonlinear data analysis according to an algorithm for pointwise transinformation used in the software package Dataplore that was performed using a calculation of transinformation between the time series \( x_1 \) and \( x_2 \) (left and right EDA).

A statistical evaluation of the PTI values (in bits) and the SHSS:C values reflecting hypnotizability was calculated using the software package Statistica version 8.0 and included descriptive statistics, Spearman correlations, and nonparametric Mann-Whitney tests for independent samples.

**Results**

The results show that, during congruent Stroop stimuli in both hypnotic conditions, the patients with higher hypnotizability display
decreased levels of interhemispheric information transmission measured by PTI calculated between left and right EDA records. Statistical analyses indicate that the values of PTI (in bits) during hypnosis discriminate between the groups of patients with higher (SHSS:C ≤ 7; n = 18) and lower hypnotizability (SHSS:C ≥ 7; n = 18) during waking hypnosis (p < .05) and also after hypnotic suggestion inducing black-white seeing (p < .01) (see Table 2). The values of PTI calculated from EDA records during hypnosis also discriminate between the groups of individuals who reported black-white seeing (n = 15) in comparison to those who did not report this experience (n = 18) during the congruent task in waking hypnosis (p < .01) and in the congruent (p < .01) and incongruent (p < .05) Stroop conditions after hypnotic suggestion inducing black-white seeing (see Table 3).

With the exception of 3 patients, all the patients with higher hypnotizability were not able to recognize color and reported black-white seeing. From these patients with higher hypnotizability, 13 reported no inner problem during the period of black-white seeing and only 2 patients described “strange” feelings during this period. The 3 patients who did not report black-white seeing had significantly higher PTI during the period of black-white seeing in congruent (Z of the Mann-Whitney test = 2.31, p = .021) or incongruent (Z = 2.19, p = .028) Stroop conditions than other patients from the group of patients with higher hypnotizability, although the SHSS:C scores of the 3 patients were not statistically significantly different from the other patients.

Table 2

<table>
<thead>
<tr>
<th>PTI state</th>
<th>Lower hypn. Mean ± SD</th>
<th>Higher hypn. Mean ± SD</th>
<th>t test t p</th>
<th>MW test Z p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTI wake-con</td>
<td>1.58 ± 0.38</td>
<td>1.75 ± 0.41</td>
<td>−1.210 .235</td>
<td>−1.085 .278</td>
</tr>
<tr>
<td>PTI wake-inc</td>
<td>1.65 ± 0.32</td>
<td>1.79 ± 0.21</td>
<td>−1.412 .168</td>
<td>−1.338 .181</td>
</tr>
<tr>
<td>PTI hyp-con</td>
<td>1.67 ± 0.31</td>
<td>1.36 ± 0.37</td>
<td>2.568 .015</td>
<td>2.314 .021</td>
</tr>
<tr>
<td>PTI hyp-inc</td>
<td>1.64 ± 0.42</td>
<td>1.49 ± 0.35</td>
<td>1.106 .277</td>
<td>0.615 .539</td>
</tr>
<tr>
<td>PTI BW-con</td>
<td>1.86 ± 0.29</td>
<td>1.50 ± 0.37</td>
<td>3.113 .004</td>
<td>2.856 .004</td>
</tr>
<tr>
<td>PTI BW-inc</td>
<td>1.74 ± 0.48</td>
<td>1.47 ± 0.33</td>
<td>1.942 .061</td>
<td>1.699 .089</td>
</tr>
<tr>
<td>hypn.</td>
<td>4.93 ± 1.28</td>
<td>8.16 ± 0.78</td>
<td>−8.906 .000</td>
<td>−4.881 .000</td>
</tr>
</tbody>
</table>

Note. PTI = pointwise transinformation (in bits); wake = waking state; hyp = hypnotic state; BW = hypnotic state after black-white suggestion; con = congruent Stroop task; inc = incongruent Stroop task; hypn. = hypnotizability; MW test = Mann-Whitney test for independent samples; df = 31.
Table 3
Statistical Comparison Between Groups of Patients Who Reported (n = 15) or Not Reported Black-White Seeing (n = 18)

<table>
<thead>
<tr>
<th>PTI state</th>
<th>non B-W Mean ± SD</th>
<th>B-W Mean ± SD</th>
<th>t-test t</th>
<th>p</th>
<th>Z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTI wake-con</td>
<td>1.65 ± 0.42</td>
<td>1.70 ± 0.39</td>
<td>−0.335</td>
<td>.7401</td>
<td>−0.325</td>
<td>.7451</td>
</tr>
<tr>
<td>PTI wake-inc</td>
<td>1.66 ± 0.29</td>
<td>1.80 ± 0.22</td>
<td>−1.424</td>
<td>.1645</td>
<td>−1.446</td>
<td>.1484</td>
</tr>
<tr>
<td>PTI hypn-con</td>
<td>1.67 ± 0.28</td>
<td>1.29 ± 0.37</td>
<td>3.285</td>
<td>.0025</td>
<td>2.856</td>
<td>.0041</td>
</tr>
<tr>
<td>PTI hypn-inc</td>
<td>1.62 ± 0.38</td>
<td>1.47 ± 0.38</td>
<td>1.110</td>
<td>.2755</td>
<td>0.651</td>
<td>.5151</td>
</tr>
<tr>
<td>PTI BW-con</td>
<td>1.87 ± 0.26</td>
<td>1.42 ± 0.36</td>
<td>4.053</td>
<td>.0003</td>
<td>3.471</td>
<td>.0013</td>
</tr>
<tr>
<td>PTI BW-inc</td>
<td>1.76 ± 0.44</td>
<td>1.38 ± 0.27</td>
<td>2.855</td>
<td>.0076</td>
<td>2.495</td>
<td>.0131</td>
</tr>
<tr>
<td>hypn.</td>
<td>5.38 ± 1.57</td>
<td>8.26 ± 0.79</td>
<td>−6.404</td>
<td>.0000</td>
<td>−4.429</td>
<td>.0001</td>
</tr>
</tbody>
</table>

Note. B-W = patients who reported black-white seeing; non B-W = patients who did not report black-white seeing; PTI = pointwise transinformation (in bits); wake = waking state; hyp = hypnotic state; BW = hypnotic state after black-white suggestion; con = congruent Stroop task; inc = incongruent Stroop task; hypn. = hypnotizability; MW test = Mann-Whitney test for independent samples; df = 31.

The relationship between hypnotizability and interhemispheric information transfer also reflects a significant correlation between SHSS:C and PTI during congruent Stroop tasks following hypnotic suggestion of black-white seeing ($r = −.41$, $p = .009$; Spearman $R = −.40$, $p = .019$) (See Figure 1). Other correlations between the SHSS:C and PTI were not statistically significant.

**Discussion**

The results indicate that decreased information transference between left and right EDA records likely reflects increased attentional focus and capacity during nonconflicting attentional tasks in hypnosis and distinguishes highly hypnotizable persons from the subgroup with lower hypnotizability. In ordinary hypnotic experiences, the increased attentional focus enables one to ignore irrelevant stimuli from the environment (Crawford, 1994; Presciuttini et al., 2014), which suggests that the decreased information transfer between the left and right side during hypnotic attentional tasks in highly hypnotizable persons likely could be explained by higher than normal levels of functional dissociations as several studies suggest (Bob, 2008; Crawford, 1994; Raz, 2008). In addition, results of the present study, suggesting decreased left-right EDA transinformation in highly hypnotizable patients, may support recent findings that decreased interhemispheric communication is involved in brain mechanisms used to increase processing efficiency.
under attentionally demanding conditions in hypnosis (Banich, 1998, 2003; Passarotti et al., 2002).

As a condition, increasing attentional involvement was used in hypnotic hallucination for black-white seeing that in highly hypnotizable patients decreased attentional distraction and conflict between word and color during incongruent Stroop stimuli that was coupled to decreased left-right information transference. In this context, decreased left-right information transfer during attention-demanding states related to Stroop congruent stimuli in hypnosis and black-white hypnotic hallucinations in individuals highly susceptible to hypnosis distinguishes patients with higher hypnotizability from the other patients. This increased hypnotic attentional involvement and decreased information transfer likely may be linked to extreme and abnormal separation of cognitive modules and subsystems and functional dissociation in the cognitive systems and may cause temporary incapability of the subsystems to communicate with each other during attentional processing (Hilgard, 1986; Woody & Bowers, 1994). These findings are in agreement with the theory of dissociated control in hypnosis that alters the actual underlying control of behavior and results in a relative weakening of the executive level of cognitive control (Woody & Bowers, 1994).

In this context, findings of the present study are also in agreement with neurophysiological hypotheses suggesting a close relationship of
the hypnotic process in susceptible individuals with selective inhibition, disconnection, and dissociation of the frontal lobe, linked to alterations of anterior brain functions such as decoupling between conflict monitoring and cognitive control functions of the frontal attentional system (Egner, Jamieson, & Gruzelier, 2005; Jamieson & Sheehan, 2004). Most likely these changes in highly hypnotizable persons may be caused by stronger attentional-filtering abilities related to changes in underlying brain dynamics between cortical and subcortical structures and interhemispheric interactions leading to attentional-shift orienting and extremely narrowing of conscious awareness (Crawford, 1994; Edmonston & Moscovitz, 1990; Feldman, 2004). This attentional shift likely may cause decreased and disconnected cognitive control disturbing ordinary integrative functions of consciousness related to disassociation of ordinary contextual experiences and “dissociated consciousness” that may occur in hypnosis and also in hypnotic-like (or hypnoid) states due to stressful and traumatic experiences (Bob, 2008; Guralnik, Schmeidler, & Simeon, 2000; Vermetten & Bremner, 2004).

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**Attentive Dissoziation in Hypnose und neuronale Verbindung: ein vorläufiger Beweis bilateraler elektrodermaler Aktivität**

**Petr Bob und Ivana Siroka**


**Stephanie Reigel, MD**

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**Dissociation attentionnelle en hypnose et connectivité neuronale: Données préliminaires de l’activité électrodermale bilatérale**

**Petr Bob et Ivana Siroka**
Résumé: Selon des découvertes récentes, les interactions interhémisphériques et la connectivité informationnelle représentent des mécanismes essentiels utilisés dans le traitement de l’information par différentes modalités sensorielles. Pour étudier ces interactions, les auteurs ont mesuré l’activité électrodermale bilatérale (AEB) chez 33 patients psychiatriques externes. Les résultats montrent qu’en présence de stimuli congruents de Stroop en état d’hypnose, les patients facilement hypnotisables manifestent une baisse du niveau de transfert de l’information interhémisphérique mesurée par la transinformation instantanée calculée à partir des enregistrements d’AEB gauche et droite. Ces résultats montrent que les variations particulières de la focalisation attentionnelle pendant l’hypnose sont liées à des changements dans les interactions interhémisphériques qui peuvent se refléter dans la connectivité neuronale calculée à partir de la mesure de l’AEB bilatérale. Ce déplacement attentionnel peut provoquer une dissociation du contrôle attentionnel perturbant les fonctions intégratives de la conscience et des expériences contextuelles.

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Disociación atencional en hipnosis y conectividad neuronal: Evidencia preliminar a partir de la actividad electrodérmica bilateral

Petr Bob y Ivana Siroka

Resumen: Según hallazgos recientes, las interacciones interhemisféricas y la conectividad de información representan mecanismos cruciales utilizados en el procesamiento de información a través de varias modalidades sensoriales. Para estudiar estas interacciones, los autores midieron la actividad electrodermática bilateral (AEB) en 33 pacientes psiquiátricos externos. Los resultados muestran que durante estímulos Stroop congruentes en hipnosis, los pacientes con mayor hipnotizabilidad manifestaron una reducción en el nivel de transferencia de información interhemisférica medida a través de una trans-información punto a punto (PTI por sus siglas en inglés) que fue calculado de registros AEB izquierdos y derechos. Estos resultados muestran que cambios específicos del foco atencional durante hipnosis están relacionados con cambios en las interacciones interhemisféricas que pudiesen estar reflejadas en conectividad neural calculada a partir de mediciones AEB bilaterales. Este cambio atencional pudiese causar un control atencional disociado que perturbe las funciones integrativas de conciencia y experiencias contextuales.

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