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Research Article

Electrodermal Correlates of Hypnosis: Current Developments

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Abstract

Hypnosis has proven to be an effective treatment in disorders that affect the autonomic nervous system (ANS). However, the studies investigating the nature of its effect on the ANS have reported contradictory results. Measurement of electrodermal activity (EDA) is an objective way to assess the activity of the sympathetic branch of the ANS. We aim to elucidate the effects of hypnosis on EDA. Here, we report the results of two studies, both investigating the psychophysiological effects of hypnosis.In the first experiment, subjects engaged in an HGSHS:A group hypnosis session to measure their hypnotizability. EDA was measured bilaterally from their wrists. We found a significant reduction in EDA levels and the number of nonspecific responses during the hypnotic induction phase. This effect was observed in all three hypnotizability groups—high, medium, and low hypnotizables.

A three-way interaction confirmed that EDA patterns on the left and right sides were characteristically different in these three groups. Left-side dominance was typical in high hypnotizables, whereas low hypnotizables were characteristically right-sided. EDA levels of the two sides remained synchronous in medium hypnotizables. During the suggestion phase, we found significant differences in EDA levels depending on the test suggestions, modulated by hypnotizability. A suggestion, harder to respond to, elicited higher arousal in high hypnotizables as compared to low hypnotizables.

In the second experiment, we performed five consecutive hypnosis sessions to confirm the reproducibility of the most prominent effect found in Study 1—a gradual decrease in the level of skin conductance during hypnotic induction. We also confirmed that this effect is independent of the hypnotizability level.

We conclude that arousal is bilaterally reduced during hypnosis induction, which is persistent across different levels of hypnotizability. At the same time, lateral differences define unique EDA patterns in the induction phase, characterizing high, medium, and low hypnotizables.

Keywords

Bilateral; electrodermal; EDA; group measurement; hypnosis

1. Introduction

Hypnosis is a state of consciousness that is characterized by focused attention and decreased peripheral awareness, accompanied by an increased capacity to respond to suggestions [1]. During hypnosis, the subjects often report changes in time sense, body image, memory, self-awareness, and volitional control, all associated with an altered state of consciousness [2]. Hypnosis is a product of the procedure called hypnotic induction [1]. A hypnotic state is achieved when individuals respond to suggestions in an automatic fashion, ignoring environmental stimuli, other than those pointed out by the hypnotist. In this state, the individual tends to see, feel, and smell in accordance with the hypnotist's suggestions, even though these suggestions may be in contradiction to the actual stimuli present in the environment. The degree to which people respond to suggestions is called hypnotizability. It is typically measured on a scale ranging from low to high. It is a stable, trait-like characteristic that does not change significantly over time; measured 25 years later, the correlation remains high with $r = 0.75$ [3]. We usually divide people into three groups—low, medium, and high hypnotizable individuals. Low and high hypnotizables are often compared in research as the two ends of the continuum [4]. There are standardized procedures to induce hypnosis and to measure hypnotizability. They involve rapport building followed by a hypnotic induction, various test suggestions, and a deinduction [5, 6].

Hypnosis has long been known as a useful therapeutic tool for various psychological and physiological disorders, including chronic headaches, hypertension, and various forms of anxiety [7]. It is particularly efficient for disorders that are characterized by changes in the autonomic nervous system. The reason for this efficacy may lie in the reduction in psychophysiological arousal and the modulation of autonomic activity [8-10]. Forbes and Pekala (1993)[8] reported that self-hypnosis training produced psychological improvements associated with reduced anxiety, reduced pulse rate, and increased skin temperature [8]. Kanji and colleagues (2006)[11] demonstrated that eight sessions of autogenic training lowered state and trait anxiety levels as well as systolic and diastolic blood pressure [11]. Hypnosis can also be an adjuvant treatment for major depression, a disorder that is associated with autonomic nervous system changes, such as decreased heart rate variability [12]. Chen and colleagues (2017) [12] found that heart rate parameters significantly improved in the hypnotic and post-hypnotic conditions compared to the pre-hypnotic condition. Thus, they concluded that hypnotic treatment might bring improvements in vegetative functions [12].

Measuring electrodermal activity can be an unobtrusive and cost-effective way to gain information about the autonomic nervous system [13]. The ease of use and the widely available technology have made the measurement of electrodermal activity (EDA) a popular tool in hypnosis research. Tools measuring skin conductance (SC) make use of the eccrine sweat glands, which are exclusively innervated by the sympathetic nervous system (SNS) [14, 15]. Thus, the tonic component of skin conductance, skin conductance level (SCL), is an excellent way to gauge the background level of the SNS. In contrast, the phasic component, skin conductance response (SCR), provides information about the autonomic responses to the given stimuli. The tonic component is characterized by slow changes; whereas, the phasic components change faster. Dawson and colleagues provided a detailed description of the different components of skin conductance [15, 16]. Determining the measurement sites for EDA is important since the density of eccrine sweat glands differs in different parts of the body. The most responsive sites to measure electrodermal activity are the palmar and plantar surfaces (for a recent bilateral analysis of traditional and alternate measuring sites, see Kasos et al., under review).

In the following section, we summarized the research results concerning the relationship between EDA and hypnosis. The studies are listed in chronological order.

Table 1 Summary of research results regarding EDA and hypnosis.

Authors & year	Purpose of the research	N	Measurement		Type of induction	Hypnotizability measurement	Main findings
			side	place			
Levine, 1930	EDA during hypnosis	6	Bi	palms of hands	-	-	No differences between waking state and hypnosis.
Estabrooks, 1930	EDA during hypnosis	20	Uni	hand	-	-	EDA decreased in hypnosis.
Davis&Kantor, 1935	EDA during hypnosis	71	Uni	medial phalanges of index and middle fingers of the right hand	-	-	Difference between active and passive hypnosis. In the active part of hypnosis, EDA resembled EDA in the awake state while in passive hypnosis resembled EDA during sleep.
Brown & Vogel, 1938	hypnosis during pain stimulation	3	-	-	-	-	No electrodermal signs of pain perception in hypnosis.
West et al., 1952	effects of hypnosis on noxious stimuli	7	-	-	-	-	Hypnotic suggestions reduce electrodermal responses to painful stimuli.
Sears & Beatty, 1956	differentiate between waking state and hypnotic state based on EDA	24	-	-	-	Davis and Husband scale of hypnotic susceptibility	No difference between the hypnosis and awake condition.
Barber & Coules, 1959	EDA during hypnosis	6	Uni	palm	-	-	Three subjects had high, and three had lower EDA during the induction. Subjects showed rising EDA during test suggestions; in addition, active suggestions (for example, suggested hallucination) elicited higher arousal.
Shor, 1962	physiological effects of	16	Uni	palm	-	-	No differences in electrodermal

	painful stimuli in hypnosis						response between hypnosis and simulator group to painful stimuli.
Tart, 1963	effects of self-reported hypnotic depth and EDA	11	Bi	foot	arm levitation,	-	Falling EDA during induction and varied EDA (rising and falling) during test suggestions.
Stern et al., 1963	how hypnotically induced amnesia alters recently acquired behavior and electrodermal correlates	14	-	-	free induction	-	No differences in EDA between hypnosis and control condition. EDA showed an increase at the beginning, followed by a decrease and an eventual increase again in hypnosis.
Edmonston & Pessin, 1966	the relation between hypnosis, learning, and EDA	22	Uni	index and middle fingers	-	not measured	No differences in skin conductance between hypnosis and control group.
Fehr & Stern,1967	effects of hypnosis on relevant and irrelevant stimuli	24	-	-	SSHS:A	HGSHS: A	The hypnosis group showed lower electrodermal orienting responses than the control group.
O'Connel et al., 1968	the relation between self-reported hypnotic depth and EDA	51	Uni right	palm	passive trance induction	HGSHS: B	Arousal correlates with hypnotizability. EDA changes during hypnosis reflect the quality of the rapport more than self-reported hypnotic depth.
Pessin et al., 1968	effects of hypnosis induction on EDA	40	-	-	the modified version of the Stanford scale	not measured	Lower number of nonspecific responses in the hypnosis condition than in the control condition.
Edmonston, 1968	effects of hypnosis on EDA	45	-	-	SHSS:B	HGSHS	The hypnosis group had lower number of spontaneous fluctuations than the control group. The groups did not differ in the number of electrodermal orienting responses.
Serafetinides, 1968	effect of hypnosis on EDA	1	-	-	-	not controlled	More frequent electrodermal responses during hypnosis compared

							to baseline.
Paul & Trimble, 1970	compared live and recorded hypnosis	30	-	-	eye fixation method	not controlled	EDA reduction during hypnosis, no difference between live or recorded sessions.
MC Ammond et al., 1971	effectiveness of relaxation and hypnosis training on stress reactions at the dentist	27	-	-	specific induction performed by the dentist	not controlled	High baseline EDA level subjects benefitted more from hypnosis and relaxation training.
Tebecis et al.,1976	EDA differences between hypnosis and awake conditions	33	Bi	palms	audio recorded self-hypnosis induction	controlled but not specified	EDA decreased during both hypnosis and control condition; however, there was a more substantial decrease in the hypnosis condition.
Bauer & McCanne,1980	effects of hypnosis on the ANS	12	Uni	medial phalanges of the index and fourth fingers	standardized audio recorded induction	HGSHS: A	Lower levels of nonspecific responses during hypnosis compared to post hypnosis. EDA was reduced in both simulator and hypnosis group.
Gruzelier et al., 1985	habituation to auditory stimuli in hypnosis	30	Bi	medial phalanges of the index and middle fingers	audio recorded eye fixation method	scale prepared for this experiment	Both high and low hypnotizables showed higher right-side skin conductance level. High hypnotizables had a lower number of nonspecific SCRs. High hypnotizables showed higher left side responses to tones during baseline compared to right side responses, and this was the opposite in hypnosis. High hypnotizables showed faster habituation to standard tones than low hypnotizables, and hypnosis had a suppressant effect on sensitization.
Gruzelier et al., 1988	differentiate between those who are in hypnosis and	18	Bi	medial phalanges of	Hypnosis induction was	Barber Suggestibility	Induction phase: higher left side SCL compared to the right side in the

	those who simulate hypnosis			the index and middle fingers	audio recorded	Scale	hypnosis group while the simulator group had higher right side SCL compared to left side SCL. Simulators showed more frequent nonspecific SCRs in the beginning stages of the induction. Hypnosis phase: both groups showed higher left side SCL. Habituation to tones facilitated in the hypnosis group, while retarded habituation characterized the simulator group.
Sturgis & Coe,1990	psychophysiological responsiveness during hypnosis	22	Uni	proximal phalanges of the non-dominant hand	the modified version of SHSS:C	HGSHS: A and SHSS: C	No baseline differences between high and low hypnotizables. No differences in EDA between high and low hypnotizables. Lower skin conductance during induction and dream suggestion than during other suggestions.
Kinnunen et al., 1994	detecting deception in the hypnotized	22	Uni	distal phalanges of the index and middle fingers of the non-dominant hand	-	HGSHS: A	No difference in SCR magnitudes between hypnosis and awake condition.
Paul et al., 1996	physiological effects of relaxation and hypnosis	60	Uni	dominant foot	eye fixation method	not controlled	Both relaxation and hypnosis produced lower SCL. Training effect reported in the hypnosis condition. Lower skin conductance in the second session than in the first session.

De Pascalis et al., 1999	psychophysiological effects of hypnotic analgesia	29	Uni	medial phalanges of the index and middle fingers of the left hand	Stanford clinical scale	SHSS: C	The fewer number of SCRs in hypnosis than in awake condition in response to pain stimulation. High hypnotizables had a lower number of SCRs than low hypnotizables. High hypnotizables had lower amplitude responses than medium and low hypnotizables. Higher amplitude responses for all in the waking condition than in hypnosis.
De Pascalis et al., 2004	evaluating the cognitive load of hypnotic analgesia	30	Uni	medial phalanges of the index and middle fingers of the left hand	Stanford clinical scale	SHSS: C	High hypnotizables had lower amplitude SCRs, in response to auditory stimuli in hypnosis, than medium and low hypnotizables.
Kekecs et al., 2016	effect of hypnosis on the ANS	121	Uni	medial phalanges of the index and middle fingers of the non-dominant hand	audio recorded WSGC	HGSHS: A	No differences between low and high hypnotizables. Lower SCL was found between pre and post induction in the hypnosis group compared to the music control condition.
Kinnunen et al., 2016	true hypnosis experience or complying	14	Uni	non-dominant hand	modified version of SHSS	HGSHS: A	In the hypnosis condition there was no difference in SCR amplitude between neutral and critical questions. SCR amplitudes differed in the control condition.

The studies are listed in chronological order. "N" –number of participants; "Uni" –unilateral measurement; "Bi"–bilateral measurements; HGSHS – Harvard Group Scale of Hypnotic Susceptibility [17]; WSGC–Waterloo Stanford Group Scale [5]; SHSS–Stanford hypnotic Susceptibility Scale [6].

The characteristic points related to hypnosis and EDA, based on the above results, may be summarized as below:

1. Regarding EDA levels, eight studies reported lower skin conductance during hypnosis compared to pre-hypnosis, post-hypnosis, or control conditions. Only one study observed a higher level of skin conductance during the hypnotic induction. Three studies found no difference between the skin conductance levels in hypnosis and control condition.
2. Many studies reported that the number of skin conductance responses (SCRs) or nonspecific SCRs were fewer during hypnosis than in control conditions. Others found that high hypnotizable individuals had less nonspecific SCRs than the low hypnotizable subjects. SCRs have smaller amplitudes in hypnosis, which is more prominent in high hypnotizables.
3. A research group published two studies with contradictory results regarding bilateral EDA.

1.1 Methodology in Hypnosis Research

Hypnosis research is riddled with methodological diversity. It would be most effective to use a standard induction procedure to ensure the reproducibility of results. Using standardized scales for measuring hypnotizability would also be beneficial to compare results.

From Table 1, it is clear that the standardized methodology of electrodermal measurements and reporting would be beneficial. Dawson (2007) [16] recommended taking the measurements from the distal phalanges of the index and middle fingers of the non-dominant hand. If those are unavailable, current studies have reported alternative measurement sites (see Kasos et al., under review). In the present study, we took the measurements from the wrists, as some of the test suggestions required use of both the hands, including fingers. SCR window should be set between 1 and 5 s after stimulus onset [15]. The minimum threshold for SCR amplitude should be set to the recommended 0.01 μS [14, 15].

Based on the above methodology, we hypothesized that:

1. SCL will reduce during the full hypnotic induction phase.
2. There will be fewer SCRs at the end of the induction compared to the beginning of the induction.
3. The above differences will be more prominent in those who are more susceptible.
4. There will be lateral differences in EDA during the hypnotic induction and during test suggestions, modulated by hypnotizability.

We performed a follow-up study to demonstrate that the most prominent effects found in Study 1 are reproducible.

2. Methods

2.1 Study 1

We recruited 38 university students as our subjects (N = 38, Mean age = 21.11, SD = 1.75), who were right-handed and had no prior experience in hypnosis. Exclusion criteria included the presence of mental illness and the use of drugs and alcohol, based on self-reporting. All participants were Hungarians (Caucasian).

Procedure: Participants were invited to take part in a group hypnosis session, where their hypnotizability was measured with the HGSHS: A (Költő, 2015). On arrival, the participants were asked to fill out an informed consent form and briefed about the experiment. We attached the electrodermal sensors to their left and right wrists. The wrists were chosen as an alternative to the traditional palmar locations because certain test suggestions required both to be close together (finger lock and hands moving together), which could cause unwanted artifacts. Participants were asked to sit comfortably but as still as possible, to avoid movement throughout the EDA measurement. A certified hypnotist read the hypnosis script, in the presence of a co-hypnotist. After the hypnosis session, EDA sensors were removed, and the participants were asked to fill out our questionnaires. At the end, the participants were debriefed.

2.2 Study 2

We recruited 19 Hungarian university students as subjects (N = 19, Mean age = 21.58, SD = 4.07), who received course credit for their participation. This optional course was about test-anxiety reduction techniques, and one of the techniques, they could experience was hypnosis. Exclusion criteria included the presence of mental illness and the use of drugs and alcohol, based on self-reporting.

Procedure: participants filled out an informed consent form, in the beginning of the semester. Their hypnotizability was measured with the HGSHS:A on the same day. On the following five occasions, each two-weeks apart, electrodermal sensors were attached to the proximal phalanges of the middle and index fingers of their non-dominant hand. They were asked to sit as still as possible to avoid movement during the measurements. An audio-recorded hypnosis script was played for the participants. In all five sessions, hypnosis was induced according to the Hungarian version of the Stanford Clinical Scale (SCS) (Morgan and Hilgard, 1978–1979), followed by suggestions with the purpose of reducing test-anxiety. The SCS induction was chosen because it is shorter than the HGSHS used in the first experiment. It was an important criterion in keeping the interventions short. The hypnosis sessions lasted between 17 and 20 min. Once the recording was over, electrodermal sensors were removed.

2.3 Data Collection and Processing

Hypnotizability scores were based on participants' reactions to the suggestions in the hypnosis session. Based on the scores, they were divided into three hypnotizability groups—i) low hypnotizables with scores 4 or below, ii) medium hypnotizables with scores between 5 and 8, and iii) high hypnotizables with scores of 9 and above.

First, we measured raw skin conductivity every 125 ms for the first 10 min of the hypnosis session (induction phase) and during suggestions (hypnosis phase). EDA was analyzed in Ledalab 3.4.8 [18]. For smoothing, a Gaussian window was applied. SCL was extracted by optimized continuous decomposition analysis.

Next, we calculated subject-independent EDA measures for the detailed analyses of the induction phase of study 1. We aimed to reduce individual variability in electrodermal levels to detect lateral changes with time, a characteristic of the three hypnotizability groups. Thus, data were standardized within individuals, using the average SCL values and the standard deviations (SD) of the 2 × 480 data points of induction phase from both wrists, to calculate the Z-scored EDA for every raw data point. Similarly, the number of SCRs was also standardized (Z-scored SCR) within individuals, using the number of SCRs in every two minutes of the induction phase measured from both wrists. The average number and SDs of SCR counts within the 2-minute intervals were used for calculating Z-scores.

Then, we calculated the laterality coefficient. This procedure standardized the values between −1 and +1. Negative numbers represent right side dominance, and positive numbers represent left side dominance [4].

Finally, we applied the analysis of variance (ANOVA) to test the effects of time, suggestions, hypnotizability, and laterality on psychophysiological responses during the induction/suggestion phase. The following EDA measures were dependent variables—Z-scored SCL, laterality coefficient values based on average SCL in every 2 minutes, and z-scored number of SCRs for each 2 minutes. We tested the within subject factors, time and side (left and right), as well as the between subject factor, hypnotizability (low, medium, and high).

3. Result

3.1 Study 1

3.1.1 Detailed Analyses of the Skin Conductance Level of the Hypnosis Induction

In the hypnosis induction phase, a standard set of preliminary instructions and suggestions are communicated to the individuals being hypnotized. The way people reach or fail to reach the hypnotic state is of vital importance; thus, we decided to analyze EDA responses to the first 10 min of the induction phase in a detailed fashion.

Based on the literature, we hypothesized a reduction in SCL during the hypnotic induction, especially in those who score high on the hypnotizability scale. The three-way mixed ANOVA on SCL during the 10-minute induction phase using side (left/right) and time as within-subject factors and hypnotizability (low/medium/high) as a between-subject factor, resulted in a prominent effect of time with $F(4,140) = 2.65$, $p = 0.036$, $\eta p^2 = 0.07$. The level of skin conductance decreased on both sides during the induction process in all three groups. Figure 1 depicts changes in Z-scored SCL during induction, averaged for the left and right hands of the three hypnotizability groups. There were no other main effects.

There were no significant two-way interactions. The analysis resulted in a significant three-way interaction of side, time, and hypnotizability with $F(8,140) = 2.49$, $p = 0.015$, $\eta p^2 = 0.13$. Low, medium, and high hypnotizables showed characteristically different EDA patterns on their left and right sides (Figure 1). The low hypnotizable individuals displayed right-side dominance, while high hypnotizable individuals displayed left-side dominance throughout the induction phase. On the contrary, the left- and right-side SCLs were similar in medium hypnotizables. High and medium hypnotizables showed lower EDA variability compared to that in the low hypnotizables. For the medium hypnotizables, SCL gradually decreased throughout the 10 minutes of induction phase. On the other hand, both low and high hypnotizable individuals showed variable EDA patterns within this timeframe.

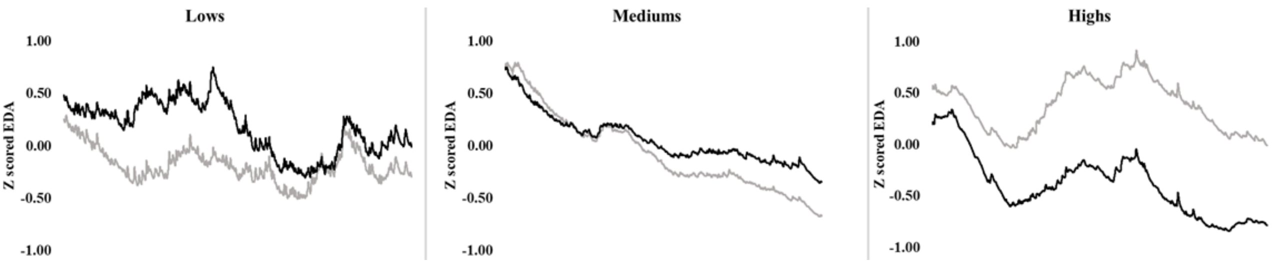

Figure 1 EDA during the induction (10 minutes). Black lines represent EDA measured from the right wrist. Grey lines represent EDA measured from the left wrist.

3.1.2 NonSpecific Responses

We predicted that fewer SCRs would characterize the end of the induction phase compared to the beginning of the induction. Findings from the literature also suggest less nonspecific SCRs in EDA patterns of high hypnotizables as compared to the low hypnotizables. Three-way mixed ANOVA analysis was performed on the number of Z-scored SCRs for every two minutes of the induction phase. We used time and side as within-subject factors, and hypnotizability (low/medium/high) as a between-subject factor. The results showed the main effect of time with $F(4,116) = 2.839$, $p = 0.027$, $\eta p^2 = 0.09$. There were no other significant main or interaction effects. The number of SCRs was reduced significantly during the induction, regardless of side or hypnotizability (Figure 2).

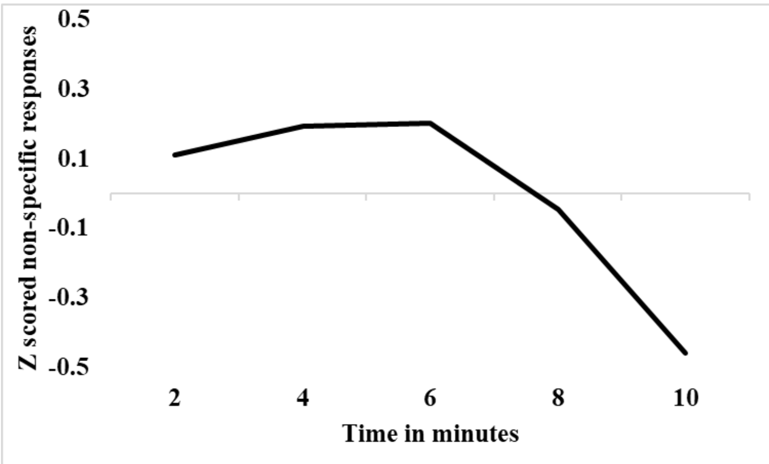

Figure 2 Z-scored nonspecific responses during every two minutes of the induction phase averaged for the two sides of EDA measurement (on the left side) and the three hypnotizability groups (on the right side).

3.1.3 Electrodermal Activity (EDA) Patterns during Test Suggestions

We hypothesized differences in EDA patterns of the three hypnotizability groups during hypnotic suggestions. First, we used a two-way mixed ANOVA to test raw SCL measured from the right-side. The nine suggestions were used as the within-subject factor, and hypnotizability was used as the between-subject factor. The results displayed a significant main effect of suggestions with $F(8,272) = 6.00$, $p < 0.001$, $\eta p^2 = 0.15$. The level of arousal changed significantly from one test suggestion to the other. A suggestion hypnotizability interaction effect was also found, $F (16,272) = 3.14$, $p = 0.001$, $\eta p^2 = 0.16$ (Figure 3, left side).

We also analyzed differences in EDA patterns during hypnotic suggestions on the left side, using the three hypnotizability groups. Similar to the right-side results, the two-way mixed ANOVA, with the suggestions as the within-subject factor and hypnotizability as the between-subject factor, yielded a significant main effect of suggestions with $F (8,256) = 4.53$, $p < 0.001$, $\eta p^2 = 0.12$. A suggestion hypnotizability interaction effect was also detected, $F (16,256) = 3.14$, $p = 0.001$, $\eta p^2 = 0.14$ (Figure 3, right side).

These results demonstrated that EDA changes significantly during the different test suggestions and that this change is modulated by hypnotizability.

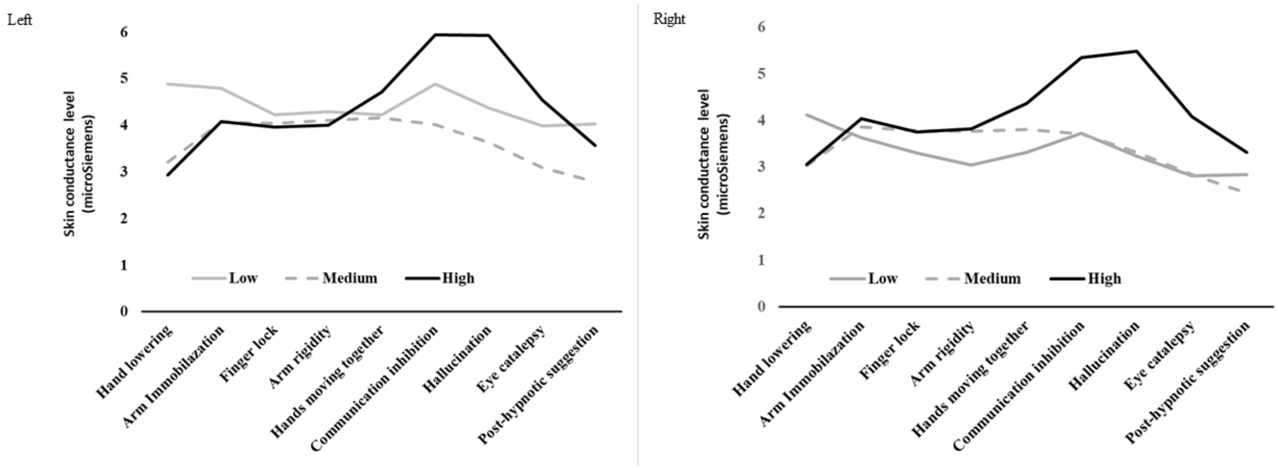

Figure 3 SCL during the test suggestion phase, measured from the left and right sides.

3.1.4 Laterality during Test Suggestions

We hypothesized lateral differences during the suggestion phase of hypnosis, modulated by hypnotizability. To test this hypothesis, we applied two-way mixed ANOVA. We used average laterality during the test suggestions as the within-subject factor and hypnotizability as the between-subject factor. They yielded no significant effects (Figure 4). Electrodermal laterality does not seem to change significantly from suggestion to suggestion. Also, there is no significant difference among the hypnotizability groups. Although, it is clear from Figure 4 that high hypnotizables remained left-dominant throughout the hypnosis, while medium and low hypnotizables were right-side dominant.

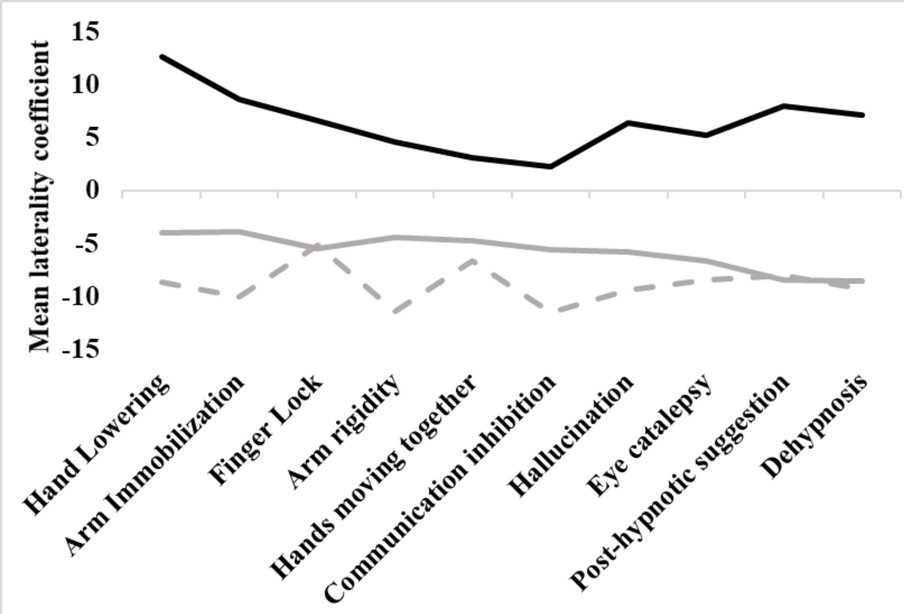

Figure 4 The laterality coefficient during the test suggestion phase. Positive numbers represent left side dominance, while negative numbers represent right side dominance.

3.2 Study 2

We performed a follow-up study to show the reproducibility of the most prominent effect found in study 1, namely, the gradual decrease in the level of skin conductance during hypnotic induction. We also examined the differences in this decrease in high, medium, and low hypnotizables. Two-way mixed ANOVA was calculated for each of the five sessions (Figure 5). We found no significant effects of hypnotizability in any of the sessions. The main effect of time was clear in the first session [$F(3,10) = 7.32$, $p = 0.006$, $\eta p^2 = 0.42$], the second session [$F(3,13) = 5.90$, $p = 0.026$, $\eta p^2 = 0.31$], the third session [$F(5,70) = 6.08$, $p = 0.012$, $\eta p^2 = 0.30$], and the fifth session [$F(6. 72) = 5.48$, $p = 0.015$, $\eta p^2 = 0.31$]. The fourth session on the other hand yielded no significant effect of time; although, this result could probably be due to the high variability of SCL. As seen in Figure 5, there was a gradual decrease in the average SCL during the induction phase, characteristic for all the hypnotizability groups, except for the low hypnotizables in session 4.

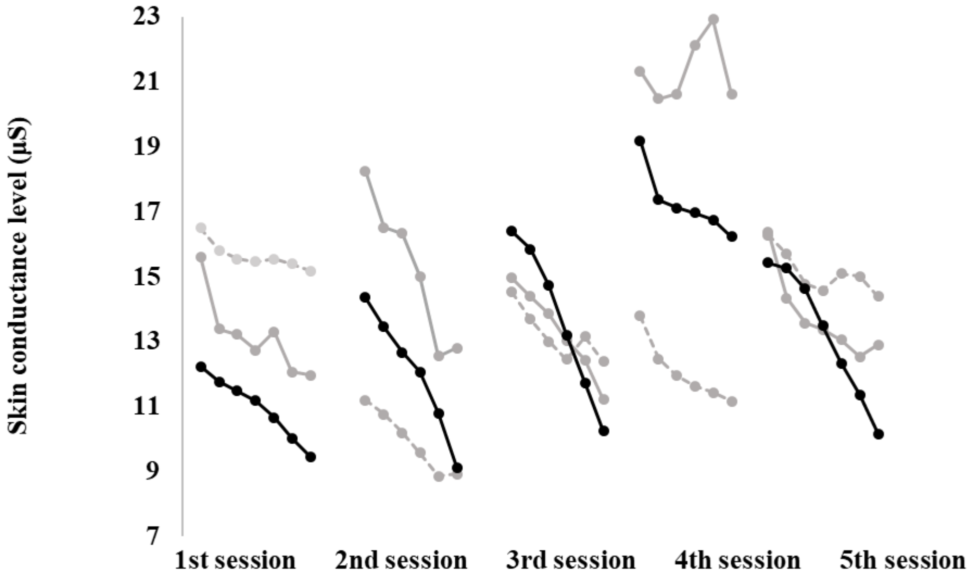

Figure 5 Skin conductance level during the induction period of the five hypnosis sessions of the experiment. Solid black lines represent high hypnotizables, dashed grey lines represent medium hypnotizables, and solid grey lines represent low hypnotizables.

4. Discussion

4.1 EDA Levels during the Induction Phase

By measuring electrodermal activity in the induction and/or test suggestion phases of hypnosis, we identified typical electrodermal attributes related to the hypnotic state. The most prominent of these characteristics is the reduction in skin conductance level (SCL). Several studies have reported similar conclusions (Table 1).

During hypnosis induction, we observed a consistent decrease in skin conductance level across the 10-minute induction phase (Study 1). This effect was bilateral and characteristically different for the three hypnotizability groups. For the low and high hypnotizables, a variable electrodermal activity (EDA) pattern was detected; whereas, in medium hypnotizables, EDA gradually decreased throughout the induction phase. Reduction of arousal in hypnosis may be one of the important factors leading to therapeutic success in treating disorders associated with higher sympathetic arousal [7].

In our follow-up study (Study 2), we intended to reproduce the above findings. Five consecutive measurements from the same subjects demonstrated that the EDA reduction effect of the hypnotic induction remained pronounced for all hypnotizability groups (Figure 5).

4.2 EDA Laterality during Hypnotic Induction

Our results show evident bilateral differences during the hypnotic induction phase. High hypnotizables display left-side dominance, while low hypnotizables display right-side dominance. A number of previous studies had also highlighted these bilateral differences [19, 20]. Our previous study also reported lateral differences during active-alert induction [4].

The medium hypnotizables showed a synchronous EDA activity of the two sides (Figure 1). Picard and colleagues (2015) [21] suggested a high correlation between the left and right sides with respect to EDA [21]. This high correlation has been confirmed in a number of studies (Kasos et al., under review) [13].

However, in high and low hypnotizables, EDA diverged on the two sides and stayed separated for the whole duration of the induction phase (Figure 1). The divergence of the two sides could be an indication of psychological distress. Picard observed right-side dominance in situations when the self was threatened [21]. Translating this to a hypnosis situation for low hypnotizables, they could be experiencing induction as a threatening situation, having to give up control to the hypnotist. This may be causing them to be distressed.

In contrast, high hypnotizables showed a strong left dominance (Figure 1). This may be explained by the multiple arousal theory [21]. According to this, positive emotions would cause EDA to be either close to synchronous or left-side dominant. For high hypnotizables, the induction process could be a positive experience. In addition, Gruzelier's induction theory hypothesizes left-side hemispheric dominance at the beginning of induction [22]. Another study focuses on the verbal processing of induction, which in right-handed subjects would lead to left hemispheric dominance [23]. The amygdala is the foremost contributor to EDA and is mostly concerned with processing emotional information [24]. Hence, we hypothesize a strong emotional component behind the observed lateral differences during the induction process.

4.3 EDA Levels and Laterality during Test Suggestions

During test suggestions in Study 1, we observed that arousal levels fluctuated from one suggestion to the other, as reported previously [25]. The arousal level of high hypnotizables was higher during the hallucination suggestion and communication inhibition suggestion, confirming the findings from prior research [26]. Elevated levels of arousal may be explained by the pronounced cognitive effort required in responding to these suggestions. This implies that responding to suggestions requires considerable effort, as suggested by proponents of the dissociative experience theory and the social cognitive theory [27, 28].

Contrary to the induction phase, lateral disposition during test suggestion was not significantly different among the three hypnotizability groups. Figure 3 shows that high hypnotizables remain left-side dominant, while medium and low hypnotizables remain right-side dominant for the whole duration of the suggestion phase. The suggestions, which are harder to respond to, such as hallucination, cause a more prominent left dominance in high hypnotizables.

The above results imply that responding to more difficult suggestions, such as hallucinations and communication inhibition, comes with a price that high hypnotizables showing higher arousal and a more left-sided electrodermal activation.

4.4 Non Specific SCRs

We hypothesized that a lower number of nonspecific skin conductance responses (SCRs) would be present at the end of the induction phase compared to the beginning. We also predicted that this effect would be modulated by hypnotizability. Our study confirmed that SCRs are fewer at the end of the induction. However, we found no evidence for differences based on hypnotizability. A reduced number of nonspecific responses could be explained by the nature of the hypnotic induction. During the induction, attention is mainly focused on the hypnotist and the inner experiences, with reduced peripheral awareness, resulting in fewer non-intended responses.

5. Limitations

The limitations of the present paper include the homogeneity of subjects in terms of their gender, age, and race. Our research could have benefitted from a higher number of participants.

6. Conclusion

In this article, we review the correlation between hypnosis and electrodermal activity (EDA) from the past 90 years of studies. We report the laterality and hypnotizability effects of electrodermal activity, during hypnotic induction and suggestion phases.

Most studies have highlighted lowered skin conductance level (SCL) during hypnosis, than pre- or post-hypnosis or in control conditions; however, contradictory findings have also been reported. In our study, we observed a prominent, bilateral reduction of SCL throughout the hypnotic induction phase, regardless of the level of hypnotizability. We also replicated this effect consistently in five independent hypnosis sessions.

Only a couple of studies have previously investigated bilateral EDA during hypnosis, with contradictory results. Our results highlight substantial differences in laterality during the hypnotic induction phase, with patterns characteristically differing depending on hypnotizability. Laterality differs throughout the hypnosis phase—high hypnotizables remained left-side dominant, whereas, medium and low hypnotizables were right-side dominant.

Nonspecific skin conductance responses (NS-SCRs) appear spontaneously, not related to any specific event. According to literature, the number of theseNS-SCRs is fewer during hypnosis than in control conditions. We, too, observe a decreasing number of SCRs in the induction phase. NS-SCR frequency typically shows great individual variety, with high levels of arousal, resulting in a higher frequency of NS-SCRs. Also, some findings indicate that high hypnotizables have less NS-SCRs than low hypnotizables. In contrast, we found no evidence for differences in the rate of NS-SCRs in relation to hypnotizability.

We conclude that arousal is reduced bilaterally during hypnotic induction and is persistent across different levels of hypnotizability. At the same time, lateral differences produce unique EDA patterns in the induction phase, defining high, medium, and low hypnotizables. The post-induction phase produces EDA that varies with suggestions. Typically, difficult suggestions produce higher arousal. Thus, our findings are novel, in terms of lateral differences of EDA in high versus low hypnotizables in the hypnotic induction phase. These results provide an objective, psychophysiological evidence for both, the multiple arousal theory and the left-side hemispheric dominance suggested by the induction theory of hypnosis.

On the basis of our findings, we strongly support that bilateral measurements should be used in hypnosis research. The ability to analyze laterality differences adds valuable information regarding the experiences of hypnosis participants. The changes that take place in a matter of a few minutes, altering one's state of consciousness, make hypnosis induction a magnificent model situation to study electrodermal laterality.

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Author Contributions

Krisztian Kasos: data collection, data analysis, statistical analysis, prepearing and writing manuscript. Luca Csirmaz: data collection, data analysis, writing and contributing to manuscript, Fanni Vikor: data collection, data analysis, contributing to manuscript, Szabolcs Zimonyi: data collection, Katalin Varga: providing essential theoretical knowledge regarding hypnosis, organizing and supervising hypnosis sessions, Anna Szekely: statistical analysis, writing and prepearing manuscript.

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Competing Interests

The authors have declared that no competing interests exist.

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