Reaction to Pain Stimulus Before and During Hypnosis Measured by Pupillary Reaction

Henriette Walter
Otto Michael Lesch
Hans Stöhr
Josef Grünberger
Karin Gutierrez-Lobos
Medical University of Vienna

The aim of this study was to investigate the analgesic effects of hypnotic pain control on experimental pain by measuring pupil reactions as an objective psycho-physiologic parameter. Twenty-two healthy volunteers (11 female and 11 male) aged between 22 and 35 years participated in the study. Pupil diameter was measured as baseline measurement (i.e., static measurement) in the non-hypnotic and in the hypnotic state. Pupil diameter changes to a standardized pain stimulus were measured in the non-hypnotic and hypnotic state and compared. Additionally, a Fourier analysis of pupil oscillations reflecting central nervous activation during the static measurement (25.6 sec) was calculated. During the hypnotic state the pain related pupil dilation was significantly smaller than during the non-hypnotic state. Pupil oscillations were significantly reduced during hypnosis.

Keywords: Hypnosis, pain control, pupil reaction

Pain affects non-conscious physiological processes as well as cognitive, emotional ones. Previously, the Gate Control Theory of Melzack and Wall (1965) promoted the concept that painful stimuli are influenced on the spinal level as well as in the brain by emotional and cognitive processes. Pain perception is modulated by activation of the reticular formation, located within the limbic system and cortical areas, leading to emotional and cognitive responses that then influence descending fibers. An overview on functional imaging by Derbyshire (1999) provides the present knowledge of alterations in brain function during pain and focuses attention on the major role of the anterior cingulate and somatosensory cortices (see also Derbyshire, Whalley, Stenger, & Oakley, 2004).

Address correspondences and reprint requests to:
Dr. Henriette Walter
Wachinger Guertel 18-20
Dept. of Psychiatry
A-1090 Vienna
Austria
Email: henriette.walter@meduniwien.ac.at
Pupillary dilation is a characteristic, non-conscious sign of acute pain, like other physiological measures (e.g., increases in heart rate and blood pressure, as well as palmar hyperhidrosis, hyperventilation, hypomotility, flight response). The smooth muscles of the iris are innervated parasympathetically and sympathetically. Mydriasis is controlled by the dilator muscle, innervated primarily by sympathetic fibers. Pupil constriction (miosis) is controlled by the sphincter muscle, which primarily receives parasympathetic innervation. Hypnosis is associated with relaxation and pupil constriction, while pain perception is followed by pupil dilation (Biller, 1997). During visual fixation and with constant, moderate, ambient light, pupils tend to be of equal and constant size. One method to trace physiological responses to pain is a software-supported measurement of pupil diameter changes. The autonomic activation measured by static and dynamic pupil measurement and the central activation measured by a Fourier analysis of all the minor pupil oscillations (usually less than 1 mm variation in size) can be tracked.

Laboratory investigations of pain stimuli are restricted to acute pain because of technical and ethical reasons. Shortcomings are therefore (1) that pain can only be induced for a short time; (2) that subjects are less emotionally involved (knowing that the pain is experimental); and (3) that the pain is expected and known to be tolerable. This different response to a sudden and unexpected painful event remains as a limitation of all experimental pain research.

In 1990, Evans investigated hypnosis effectiveness in different types of pain (Evans, 1990). For acute pain, he recommended hypnotic suggestions focusing on anxiety-reduction and emphasis on minimizing the importance of the pain. For chronic pain, Evans suggested directly confronting the pain under hypnosis, dealing with both the pain’s physical and psychological effects on the patient (Evans, 1990). Based on these and similar findings, we generally have two principle methods for pain control: The symptom-related and the problem-related approach.

In the authors’ view, the symptom-related pain control suits for an acute intervention (accidents, acute pain of any kind) and focuses on analgesia and symptom relief only (relief of acute pain and anxiety). It deliberately does not take into consideration that pain is a warning sign of the body and the aim is to get rid of the pain. Therefore, it can only be applied acutely. If pain continues, mere symptom relief can no longer be the method of choice. In these patients, it is necessary to search for etiological factors to find the reasons for the individual pain sensation.

The problem-related approach attempts to gain control over pain and over problems contributing to the persistence of pain. It fits well for treatment of chronic pain, because it directly addresses pain reduction as well as the problems associated with, or related to, the specific chronic pain. These problems can include fear of death as in chronic cancer pain, general anxiety if a pain does not diminish gradually, or a fear of immobility as in chronic rheumatism.

This study aimed at investigating the pupil reactions to pain stimuli in a non-hypnotic and hypnotic state. As a result of a hypnotic trance, the balance of the autonomic nervous system is shifted toward the parasympathetic side. This effect has mainly been cited in teaching textbooks (e.g., Kossak, 1993) and is widely accepted, but it has not been a major subject of scientific concern. If the assumption is correct, then the pupil dilating effect of pain is expected to be less pronounced during a hypnotic state than in a non-hypnotic state of consciousness because the pupils’ dilating muscles predominantly receive input from the sympathetic system, and constriction is due to parasympathetic activity.
Method

Participants
Twenty-two healthy, medication-free participants, aged 22 to 35 years, volunteered for the study (11 female and 11 male participants) after having been informed of both the study design and procedures, as well as about possible risks. All participants were selected from an available group of 110 persons who had been tested previously with the Stanford Hypnotic Susceptibility Scale Form C. The scores of the group used in the current study had been ascertained to be 8 or more. We chose this highly susceptible group because hypnotic susceptibility is postulated, though contradicted by Barber (1996), to be a good predictor of hypnotic sensory analgesia (Weitzenhoffer & Hilgard, 1962; Hilgard 1965; Hilgard & Hilgard 1975).

Design
We used a repeated measures design with subjects serving as their own controls, and we performed four measurements: baseline, pain reaction (non-hypnotic state), baseline (hypnotic state) and pain reaction in hypnosis. First, for baseline, the static pupil measurement was taken with the head in a fixed position and with open eyes (measurement 1). After administration of the pain stimulus (0.5 seconds) on the right hand, the dynamic pupil measurement followed (measurement 2). Third, a hypnotic trance was induced, and baseline was measured after eye opening (measurement 3) and after deepening and induction of glove anesthesia. The participants again opened their eyes, placed their heads in the fixed position for pupil measurement and the pain stimulus was applied on their right hand (for 0.5 seconds). During the pain stimulus (0.5 seconds), the dynamic pupil measurement was taken (measurement 4). In order to exclude diurnal variation, all participants were tested at the same time (between 1:00 and 2:00 p.m.). Pupil oscillations were also recorded and calculated with a Fourier analysis.

Pain Induction
Several methods exist for experimental pain induction. Methods such as pain induction by pressure, heat, cold, ice water and frozen alcohol spray have been utilized (Hilgard, Morgan, & Mac Donald, 1975; Hilgard & Hilgard, 1975; Crawford, Knebel, & Vendemia, 1998).

Prior to this study, and with different participants, we had undertaken a test series in which we used an ice spray (di-methyl-ether) which had been proven to be effective and safe (no allergic reactions). To elicit pain in this study, we again used di-methyl-ether in our investigation. After the (software-guided) baseline static pupil measurements we delivered a focused application of the ice spray for half a second (minus 50 Celsius) on the back of the right hand. The pain reaction was then measured with dynamic pupil measurement.

Hypnosis Induction
For the pain control, we did not focus on the affective component of pain (which can be expected to be rather low in an experimental setting); instead, we used a glove anesthesia metaphor. After the induction period with eye closure, rapport, pacing, leading and its repetition, we used direct and indirect relaxation suggestions (e.g., “while you feel the contact of your body to the chair, you may feel relaxed and perceive a special kind of inner
freedom”; “the easier you breathe in and out, the more relaxed you will become…”). Once participants had been hypnotized, we utilized the laboratory situation (e.g. “the science laboratory is the place where you can ask yourself questions… the place where you can really be curious,” etc.) and we used further suggestions of relaxation for trance deepening already indicating the sensory detachment to come (e.g., while leaning back, you can leave your body and conscious mind here, asking questions, receiving answers, while letting your inner self go to a place where you can feel safe and fine, where you can relax even more deeply; doing all these things at the same time, you are able to just leave your right hand here to become more and more unsusceptible”). Finally a short metaphor of glove anesthesia (…”remember the feeling or imagine a glove that is much too tight…and you have put it on your hand…”) was used to develop sensory dissociation and replace it by a feeling of numbness on the back of the right hand where later the pain stimulus was applied. The script was standardized and each participant underwent the same hypnotic session during which the measurements took place (i.e., no recordings were used). Hypnosis was always provided by the same person, an experienced therapist, trained in classical hypnosis and Ericksonian approaches to clinical hypnosis. The only variable parameter was time, but this was minimal (plus or minus 5 minutes).

**Pupil Measurement**

The method of measuring static (baseline) and dynamic (stimulus dependent) pupillary reaction has been published elsewhere (Grünberger, Linzmayer, Grünberger, & Saletu, 1992). With a fixed head position, a camera which is connected to a computer, measures over a period of 25.6 seconds the vertical pupil diameter (static pupil measurement). Subsequent to baseline measurements, a pain stimulus of minus 50 degree Celsius for 0.5 seconds was applied, followed by the dynamic pupil measurement (i.e., latency, relative and absolute change, and half-life time of the change). Additionally, a Fourier analysis calculated the oscillations of the pupil. During the 25.6 seconds of the static measurement, the oscillations were also recorded, reflecting the activation of the brain.

Before calculating the Fourier analysis, blinking of the eyelids was excluded. This was achieved by a technique called the “Grünberger’sche Glättung,” which means that a computer program continuously compares each incoming signal’s value with the next one, calculating the difference between these values. If the calculated difference exceeds a pre-defined reference value, the incoming signals are continued to be recorded until the values are within the reference range again. Both values, which mark the start and the end of an eye blink, are then connected linearly. Thereby, the values which exceed the range are excluded from further data processing. For the Fourier analysis, five individual frequency bands: 0.0 to 0.2, 0.21 to 0.4, 0.41 to 0.6, 0.61 to 0.8, 0.81 to 1 Hz. and also the whole power spectrum was used (Grünberger, Linzmayer, Grünberger & Saletu, 1994).

**Results**

As the analysis of the data by Levene test showed that the data were not normally distributed, we chose non-parametric tests for data analysis. To compare the dependent variables of 22 subjects and four measurements each (baseline, pain stimulus, baseline-hypnosis and pain stimulus-hypnosis), we used the Wilcoxon-Test (Sachs, 1972). Wilcoxon is the most useful test to see whether the values in two samples differ in size. It resembles the median test in scope but it shows a higher sensitivity.
A statistically significant reduction of the baseline value (the last measured value before stimulus application) was found when the pre-hypnotic and the hypnotic conditions were compared ($z = -1.96, p < 0.05$). We found that the pain stimulus was significantly reduced during hypnosis when compared to non-hypnosis when measured by pupil dilation. In comparing pupil dilation in the two groups, the pain-induced maximal pupil dilation (i.e. maximal pupil diameter change) differed significantly between the measurements before and during hypnosis ($z = -3.20, p < 0.01; z = -2.29, p < 0.05$, Wilcoxon-Test); (see Figure 1). The decrease of the area under the curve, which represents the maximal dilation of the pupil after pain, was significant ($z = -1.83, p < 0.05$).

The absolute pupil diameter change represents the difference between the initial value and the minimal stimulus value. The pain related absolute pupil diameter change was less during the hypnotic state when compared to the non-hypnotic state ($z = -2.07, p < 0.05$; Wilcoxon-Test see Figure 2).

Figure 1: During hypnosis the maximal pupil diameter change is significantly reduced during hypnosis.

Figure 2: The absolute change of pupil diameter is reduced during hypnosis for the pain condition.
CNS Deactivation During Hypnosis

As arousal is related to pupil oscillations, the Fourier analysis showed that the oscillation amplitudes decreased during the hypnotic state (representing a central nervous deactivation) in the frequency band of 0.0 to 0.2 Hz. Also, the power spectrum of the oscillation amplitudes decreased during the hypnotic state ($z = -2.17, p < 0.05; z = -1.82, p < 0.05$; see Figure 3).

**Fig. 3. Fourier analysis of pupil oscillations in the frequencies 0.0 to 0.2 Hz as well as over the whole power spectrum: amplitude reduction (indicating the central nervous deactivation)**

Discussion

After exposure to pain stimuli, the changes in pupil diameter before and during hypnosis show significant differences. The finding, that the constrictive effect of hypnosis can be detected in the baseline measurement values (non-hypnotic and hypnotic state) and even under the dilating effect of pain, indicates the deactivation of the autonomic nervous system during hypnosis. This finding is in accord with the clinical and research observations, showing that hypnosis with relaxing suggestions can lead to attenuation of arousal (Spiegel, Bierre, & Rootenberg, 1989). The sympathetic nervous system deactivation, directly associated with a shift toward an activation of the parasympathetic system, is reflected by psychophysiologic reactions typical for relaxation.

As predicted, the baseline pupil diameter was smaller during the hypnotic state when compared to the non-hypnotic state. In the non-hypnotic state, the pain stimulus resulted in an average pupil dilation of 4.4 mm, while in the hypnotic state the dilation was only 3.85 mm. We interpret this finding to be a physiological process characteristic for hypnosis. We are tempted to relate these findings to prefrontal and frontal activations found in neuroimaging studies (Walter et al., 1994; Walter, 1994a; Rainville, Duncan, Price, Carrier & Bushnell, 1997; and Rainville et al., 1999). Functional imaging correlating brain activation and subjectively perceived pain intensity showed the areas activated are the anterior cingulate, the prefrontal cortex, and frontal cortical areas (Coghill, McHaffie, & Yen, 2001). We are well aware that studies have to be done confirming these findings and relating them to other measurement methods.
The oscillation frequency analysis of a band 0.0 to 0.2 Hz and of the power spectrum including all frequency bands showed a significant decrease of the amplitudes after the pain stimulus during the hypnotic state (Figure 3). Both findings indicate a decrease of arousal which can be interpreted as an expression of the relaxed hypnotic state and presumably also of the reduced pain perception. The results of this study indicate that the often cited “vagotonus” achieved by hypnosis is able to alter autonomic functions in response to hypnotic suggestions.

This study belongs to the category of basic research whereby its value for clinical hypnosis can only be indirect. In this study, we focused on analgesia, while in clinical hypnosis pain control is achieved by various additional processes. Association and imagination techniques, utilizing the situation, and a modeling of the affective components of pain, to name only a few techniques, will often generate success, as emphasized in the recent overview by Feldman (2004).

Non-pharmacological adjuncts have been suggested as an efficient safe means of reducing discomfort and adverse effects during medical procedures (Lang et al., 2000). According to a separate analysis of the Lang et al. (2000) data, using hypnosis reduced the cost of intravenous sedation in the procedure room by $130 per patient. In addition, hypnosis cut procedure room time by 17 minutes, even though the hypnotic relaxation technique itself required 10 minutes to administer. In addition, hypnosis had a long-lasting effect on pain and anxiety; study researchers observed that even 4 hours after the start of the procedure, hypnotized patients were doing much better. Our results provide scientific evidence for hypnosis as an adjunct in pain relief. With this study, the authors hope to encourage the use of hypnosis by contributing to the demonstration of the reliability of hypnotic interventions for pain control.

References


CNS deactivation during hypnosis


