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Local and systemic vasodilation following hypnotic suggestion of warm tub bathing

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Abstract

During hypnosis it is easy to induce hallucinations having, for the hypnotized subject, the characteristics and the concreteness of reality. This study was performed to put in evidence the physical effects of hypnotic suggestion of warm tub bathing.

18 volunteers screened for high hypnotizability were studied. They underwent suggestion of forearm in warm water (30 min), suggestion of body in warm water (30 min), and hypnosis without any thermal suggestion (30 min), while blood pressure, heart rate, body temperature, forearm flow and resistance, stroke volume, cardiac index and total peripheral resistance were monitored.

During suggestion of forearm in warm water, local vasodilation was recorded, with decrease of forearm resistance (−18%, $P<0.01$) and increase of forearm blood flow (+43%, $P<0.01$) like in real local passive warming. During suggestion of whole-body in a warm water tub, there was a systemic vasodilation with decrease of total peripheral resistance (−29%, $P<0.01$) and increase of cardiac index (+54%, $P<0.01$), like in real total-body passive warming. Body temperature, arterial blood pressure and heart rate were unchanged. During simple hypnosis (sham procedure) no haemodynamic variations were observed. These results are in keeping with the possibility to induce through hypnotic suggestion of heat a physical pattern that is typical of hyperthermia, even without increase in body temperature.
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1. Introduction

Hypnosis is characterized by altered consciousness. In this state, attention is focused monothematically on a particular idea. Although sometimes occurring during normal life, such a condition is favoured in clinical hypnosis by an expert operator. In this condition it is possible to administer special suggestions (thermal, tactile, visual, auditory, coenesthesic) that, due to the high level of attention and to the characteristics of altered consciousness, raise to special relevance and can be experienced as belonging to real world (Kaffman, 1981; Rhodes and Rhodes, 2003; Bryant and Mallard, 2005). During hypnosis, hallucinations having for the hypnotized subject the characteristics and the concreteness of reality can therefore be induced. This is the case for the sense of heat, which was chosen in this study because it is simple to obtain and because its cardiovascular consequences are easily measurable. Subjective sense of heat is taken for granted during hypnosis and even during bio-feedback (Charkoudian, 2003). Nevertheless, the present study was also aimed at clarifying whether or not the subjective sense of heat was accompanied by the instrumental findings that are typical of thermal vasodilation. It is in fact still uncertain whether such experiences are mere hallucinations, or rather are accompanied by real and measurable physiological modifications. Despite the common belief that cardiovascular functions are controlled by

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conscious and unconscious activity of the mind (what constitutes the basis of the so-called psychosomatic medicine), very little information is available concerning the influence of non-conscious mechanisms on cardiovascular system and on other physical items such as the possibility of modifying body temperature, eliminating warts, producing blisters or modifying the colonic pressure (also reducing spasms) and the immunitary response (Ewin, 1992; Worwell et al., 1992). In a previous study we had the opportunity to demonstrate that highly hypnotizable subjects registered hemodynamic changes compatible to real phlebotomy when suggested to underwent an imaginary 300-ml blood letting in hypnotic setting, showing that the hemodynamic consequences of phlebotomy were due to cortical participation to the event rather to hydraulic subtraction of blood (Casiglia et al., 1997).

Aim of the here described study was to monitor body temperature and haemodynamics before and during hypnotic suggestion of heat, in order to put in evidence the physical effects of hypnotic suggestions, if any. Forearm vasodilation during suggestion of local heat, as well as total-body vasodilation during suggestion of immersion of body in warm water, were expected to be obtained.

2. Materials and methods

2.1. Study protocol and subjects

Eighteen healthy, young, highly hypnotizable volunteers whose general characteristics are summarized in Table 1 were confined to bed until reaching haemodynamic stability. Then, they underwent hypnotic induction followed by 30-min hypnotic hallucination of forearm in warm water, while the cardiovascular parameters specified below were recorded. After reaching once again haemodynamic stability, they underwent 30-min hypnotic hallucination of whole-body in warm water.

As a control, the same subjects also underwent in another day 30-min hypnosis without any thermal suggestion, while the same cardiovascular parameters were recorded. The study design is summarized in Table 2.

The study subjects were recruited between a list of healthy volunteers. According to hemispheric asymmetry hypothesis (Gruzelier et al., 1984), a first selection by the Handedness Scale (Annett, 1970) was performed in order to identify those who were strongly right-handed. The selected were administered a 12-item Harvard Group Scale of Hypnotic Susceptibility Form A (Shor and Orne, 1962; De Pascalis et al., 2000) and the small group version of the 12-item Stanford Hypnotic Susceptibility Scale Form C (Crawford and Allen, 1982). Only those subjects who consistently scored 10 to 12 in hypnotizability on the two measures (highly hypnotizable) participated in the present study. The subjects were also previously defined as eligible for hypnosis on the basis of historical questionnaire, of personal interview with the staff and when necessary of a Minnesota Multiphasic Personality Inventory 2 procedure. This was aimed at screening out the subjects with borderline personality, more prone to show unwanted effects during hypnotic dissociation.

The research described in this papers adheres to the principles of the Declaration of Helsinki. All subjects gave written informed consent to the procedure. Each one was preliminarly and personally informed about the aims, methods and possible risks of the procedure, and had the opportunity to ask all questions that he/she considered necessary. Local Ethics Committee approved the protocol.

Table 1
Anagraphic, anthropometric and baseline values of the 18 subjects under study

Age (years)	27.4±2.9
Male/females	4:14
Body mass index ($kg \times m^{-2}$)	21.6±2.3
Systolic blood pressure (mm Hg)	120.8±11.4
Body temperature (°C)	34.2±2.5
Diastolic blood pressure (mm Hg)	74.2±6.5
Heart rate (bpm)	78.1±14.9
Stroke volume (ml)	57.4±9.7
Cardiac output ($l \times min^{-1}$)	4.3±1.1

Mean±standard deviations.

Table 2
Study design

Time (min)	Action	Duration
Day of the experiment		
0	Subject put in bed	–
1 to 30	Baseline measurements	30 min
31 to 40	Hypnotic induction	10 min
41 to 70	Suggestion of forearm in warm bath; measurements	30 min
71 to 80	Rest in bed remaining in hypnosis until baseline values	10 min
81 to 110	Suggestion of body in warm bath; measurements	30 min
110 to 120	De-hypnotization	10 min
Day of shame experiment (intra-subjects control)		
0	Subject put in bed	–
1 to 30	Baseline measurements	30 min
31 to 60	Rest in bed without any hypnotic induction; measurements	10 min

2.2. Plastic monoideism

2.2.1. Preliminary sitting

Some days before the experimental procedure, study subjects individually underwent hypnotic induction through verbal suggestions with cues of relax and well-being. Each subject in turn was made to relax in response to verbal commands. Through the voice of an expert hypnotist, the subject was guided towards focusing his/her attention on a single idea, excluding any other external or internal stimuli. A traditional hypnotic induction was used, consisting in a brief enumeration coupled with suggestions of general well-being, palpebral heaviness, regular deep breathing, and staring at a point. After spontaneous eyelid closure was obtained, subjects were invited to concentrate on their own body from their feet to the head, whilst a feeling of heaviness and muscular relaxation was being suggested. The verification of passive abandon was based on some signals, such as eyelid closure, arm levitation, the easing of facial tension, the lower jaw dropping down with a mild opening of mouth, and on

the slowing of breathing rate. The analysis of these signals enabled the operators to understand if subjects were really hypnotised, aimed at maintaining or modifying this condition by means of continuous appropriate suggestions.

Aim of this preparatory procedure was to establish a valid interpersonal relationship between the operator and the subject, in order to favour rapid and valid monoideism in the occasion of the following experimental sitting. To reduce the time needed for induction, post-hypnotic conditioning was predisposed in all subjects during preliminary sitting.

2.2.2. Experimental sitting

Once a valid monoideism was obtained, the special suggestions aimed at inducing thermal hallucinations were administered. Thermal hallucination was chosen as the target of the study because it is easy to obtain and because body temperature and local and systemic consequences of temperature increase can be easily measured in clinical setting. In details, warming of right forearm was suggested by hallucinating its immersion in a tub full of warm water. Aim of this procedure was to clarify whether the sensation of warmth experimented by the subjects had an instrumental equivalent, or was simply the expression of a subjective hallucination. Forearm arterial resistance and arterial flow were contextually monitored throughout the study in order to ascertain whether the increase of temperature of the segment, if any, was attributable to vasodilation. Arterial blood pressure, heart rate, and central haemodynamics (cardiac output, cardiac index = cardiac output / body surface area, stroke volume) were simultaneously monitored to clarify whether the local vasodilation, if any, derived from systemic modifications or rather from redistribution of blood flow, as previously demonstrated by our group during normal sleep (Casiglia et al., 1996, 2000). This first experiment lasted 30 min.

After the end of the above described experiment and after reaching haemodynamic stability to avoid cross over effects, whole-body immersion in a bath tub of warm water for 30 min was hallucinated, while the cardiovascular parameters specified above were continuously monitored. Aim of this procedure was to put in evidence the cardiovascular modifications due to thermal systemic vasodilation, if any, i.e., reduction of total peripheral resistance, increase of cardiac index or reflex tachycardia.

At the end of this last period, the subject's usual consciousness was gradually restored. During the two above mentioned periods, subjects were constantly observed and followed, in order to maintain and keep constant the hypnotic level. Although in clinical practice subjects may occasionally fall asleep during hypnosis, this was impossible in the context of the present study as they were never abandoned during the 30-min experimental periods and their attention was constantly kept active by the operator by means of verbal instructions. The level of attention was checked through periodical requests of actions such as answering simple questions, moving fingers, levitating a hand or opening eyes. Five doctors were continuously present along the experiment. No amnesia was induced, and at the end of the experimental setting any subject was asked about his feelings during the experiment in order to be reassured about quality, intensity and continuity of his hypnotic experience. Finally, the haemodynamic response obtained during hypnosis in the present study was completely different from that previously obtained by the same authors in the context of normal sleep (Casiglia et al., 1996, 1999, 2000).

As a control, the same subject underwent in a different day a sham procedure represented by simple hypnotic induction without any thermal suggestions while lying in bed for 30 min, without any suggestion but relaxation. Aim of this procedure was to observe if hypnosis per se produced any cardiovascular effects.

2.3. Monitoring

Cardiovascular parameters were monitored before and during hypnosis. Body temperature (in °C) was measured at right forearm with a flat-probe electronic thermometer (0900.0519 device, Testo AG, Berlin, Germany). At the end of the experiment, each subject was asked to specify the approximate subjectively perceived temperature of hallucinatory warm water.

Arterial blood flow indexed for the volume of tissue (in $ml \times min^{-1} \times dl^{-1}$) was measured at the same forearm with a strain-gauge plethysmograh (Angioflow, Microlab Electronics, Padova, Italy). This method, validated and largely used by our group (Casiglia et al., 1996; Casiglia et al., 2000), entails periodic occlusion of venous outflow by a cuff automatically inflated at over-venous and under-diastolic pressure and the measurement of arm volume by indium–gallium-in-silicone strain-gauge. In such conditions, segmental blood inflow is proportional to arterial flow. Repeatability and precision of this method have been demonstrated (Casiglia et al., 1996; Casiglia et al., 2000).

Blood pressure (in mm Hg) was measured at 1-min intervals by a trained medicine doctor with a mercury sphygmomanometer. Mean blood pressure (in mm Hg) was calculated from diastolic + 1/3 pulse pressure.

Forearm arterial resistance (in $mm\ Hg \times min \times dl \times ml^{-1}$) was calculated from the mean blood pressure / arterial flow ratio.

Stroke volume (in ml) and cardiac output (in $l \times min^{-1}$) were measured with an impedance cardiograph featuring enhanced bio-impedance signal morphology analysis (Physio Flow TM-Lab-1, Manatec Biomedical, Ebersviller, France), that also recorded heart rate (in beats per minute, bpm) from RR-intervals (Richard et al., 2001).

Total peripheral resistance (in $mm\ Hg \times min \times l^{-1}$) was calculated from the mean blood pressure / cardiac output ratio.

2.4. Statistical analysis

The minimal number of subjects to be studied was determined through literature and previous experience of the same laboratory. Based on plausible flow and peripheral resistance variations during thermal suggestion (Mittleman et al., 1992; Casiglia et al., 1997, 2000), power analysis for $\alpha = 0.05$ indicated that 15 subjects were sufficient to avoid β error (Pearson and Hartley, 1957); 20 were therefore recruited, but 2

interrupted the study for personal problems leaving a pool of 18 available subjects having a complete dataset.

Continuous variables were expressed as mean±standard error and compared with multiple analysis of covariance (MANCOVA) and the Bonferroni's post hoc test. Repeated-measures MANCOVA was used to analyze the curves generated during the experimental and control settings, respectively; between-subjects was employed to compare curves to each other, and within-subjects analysis to ascertain whether the differences between the points of each curve were significantly different from baseline. Statistics were adjusted for age, body-weight and baseline values. Correlations were evaluated with the Pearson χ^2 test. The null hypothesis was always rejected for a probability (P) of 0.05 or less.

3. Results

3.1. Hallucination of "forearm in warm water"

Forearm temperature showed a mild and insignificant increase from 34.2±2.5 (confidence intervals, CI, 33.0–35.5) to 34.5±2.7 (CI 33.1–35.9) °C during this phase. Forearm resistance progressively and significantly decreased, reaching −21.4% ($p<0.01$) at the 30th minute of hallucination (Fig. 1, upper panel, –●–). Forearm flow consensually increased in comparison to baseline mirroring the resistance fall (Table 3), like in a real warming (Keatinge and Evans, 1961). Blood pressure, heart rate, stroke volume, cardiac index and total resistance did not deviate from baseline values (Table 3). After de-hypnotization, subjects stated that the temperature of hallucinatory water ranged between 30 to 60 °C (43±9 °C in average).

During simple hypnosis, in the absence of any experience of immersion of forearm in water, forearm resistance (Fig. 2, upper panel,—Δ—), as well as the other monitored parameters (Table 3), were unchanged in comparison to baseline.

3.2. Hallucination of "body in warm water"

When subjects experienced immersion of body in warm water, total arteriolar resistance progressively and significantly decreased, reaching −29% at the 30th minute of hallucination

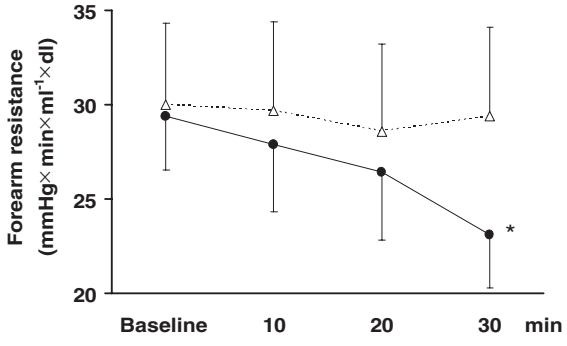

Fig. 1. Forearm resistance detected at baseline, during hypnotic suggestion of immersion of forearm in warm water (●) and during mere hypnosis without any thermal suggestion (Δ); *$P<0.01$ vs. baseline.

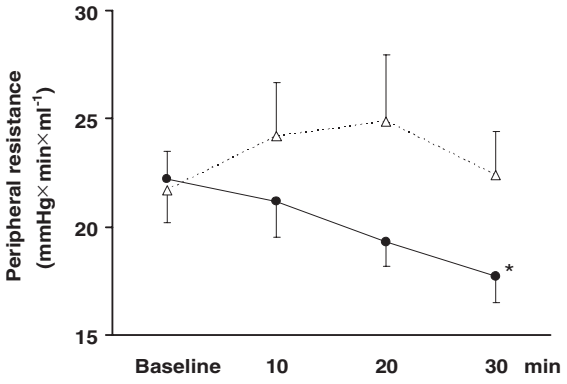

Fig. 2. Total peripheral resistance detected at baseline, during hypnotic suggestion of immersion of the whole body in warm water (●) and during mere hypnosis without any thermal suggestion (Δ); *$P<0.01$ vs. baseline.

(Fig. 2, lower panel, –●–), while cardiac index significantly increased in comparison to baseline mirroring resistance fall (Table 3), like in a real warming. This latter increase was wholly attributable to and directly correlated with ($r=0.82$, $P=0.03$) stroke volume rise, while heart rate was unchanged. During suggestion of body in warm water, forearm flow also progressively increased from the baseline value of 3.4±1.3 ml×min^{-1}×dl^{-1} to the final value of 5.8±2.2 ml×min^{-1}×dl^{-1} ($P<0.01$) at the 40th minute of hallucination, as a simple

Table 3
Blood pressure, heart rate, cardiac index and stroke volume (mean±standard deviations) during hallucination of forearm in warm water ("Forearm warm") and of body in warm water ("Whole-body warm"); mere hypnosis without any thermal suggestion is also shown as a control

	Baseline	10 min	20 min	30 min
Systolic blood pressure (mm Hg)				
Forearm warm	123±17	123±14	123±13	121±15
Whole-body warm	121±11	121±11	121.5±11	128±31
Neutral hypnosis	123±8	125±8	126±10	125±10
Diastolic blood pressure (mm Hg)				
Forearm warm	77±11	80±9	80±6	81±8
Whole-body warm	75±6	79±5	79±5	82±15
Neutral hypnosis	75±5	79±7	78±5	78±5
Heart rate (bpm)				
Forearm warm	80±16	78±14	80±14	81±14
Whole-body warm	81±16	79±14	80±14	81±15
Neutral hypnosis	80±15	84±20	80±18	84±18
Rest flow				
Forearm warm	3.5±1.3	4.3±1.8	4.4±	4.8±2.2
Whole-body warm	3.5±1.3	4.6±2.5	4.6±2.3	4.7±2.4
Neutral hypnosis	3.5±1.3	3.9±1.8	4.0±1.8	3.9±1.8
Cardiac index (l×min^{-1}×m^{-2})				
Forearm warm	2.8±0.9	3.1±1.3	3.1±1.1	3.3±1.1
Whole-body warm	2.9±1.1	3.1±1.4	3.2±1.2	3.7±1.6
Neutral hypnosis	2.8±1.1	3.1±1.7	2.7±1.1	2.9±1.1
Stroke volume (ml)				
Forearm warm	61.0±16.7	62.7±18.8	65.8±18.4	69.3±26
Whole-body warm	57.9±9.8	63±19	67±18.4	74.1±27
Neutral hypnosis	58.7±9.3	58.1±17.1	58.4±11.8	58.4±13.8

epiphenomenon accompanying cardiac output increase. Body temperature mildly and insignificantly increased to 36.1±0.4 °C. After de-hypnotization, subjects stated to have experienced subjective water temperature ranging between 35 and 60 °C (44±10 in average).

During mere hypnosis, in the absence of any experience of immersion of forearm in water, total resistance (Fig. 2, lower panel, —Δ—), as well as the other monitored parameters (Table 3), were unchanged in comparison to baseline.

4. Discussion

Briefly, in this study local vasodilation was observed during hallucinated sense of heat at forearm, while during hallucination of total-body sense of heat systemic vasodilation was recorded.

The increase of measured temperature was mild and insignificant. This was not a surprise, both because skin temperature is not a reliable marker of body temperature, and also because other authors found nothing more than a mild increase of peripheral and core temperature even during real immersion in warm water (Kenny et al., 1996; Doering et al., 1999). Lacking of systemic effects during local vasodilation was also expected, as blood redistribution to limbs with local overflow keeping constant central haemodynamics is a well known phenomenon (Casiglia et al., 1996, 2000). When, in a later phase, hypnotic suggestion of whole-body warm tub bathing was administered, peripheral resistance decreased and cardiac index increased via stroke volume rise, like in real body heating.

Despite systemic vasodilation, no increase of heart rate was observed during this phase probably because of the concomitant effect of relaxation that is typical of hypnosis. This relaxation is also documented by the constantly lower resistance values recorded during hypnosis than during control.

The possibility that haemodynamic effects may be mediated by hypnotic suggestions has already been suggested. In a previous study, we induced in blood donors the physical pattern which is typical of blood loss (with hypotension and reflex vasoconstriction) by hallucinating with hypnosis a 300-ml phlebotomy, without any needle and without any real reduction of blood volume (Casiglia et al., 1997). The results shown in the present study, highlighting a physical pattern that is typical of hyperthermia during simple suggestion of body heating, without increase in body temperature, are in agreement with this line of research.

The literature on this topic is conflicting. A rise of cutaneous or mucous temperature was previously observed during suggestion of heat (Kistler et al., 1999; Piedmont, 1981; Raynaud et al., 1994) but also during non-thermal hallucinations (Wallace and Kohoszka, 1992) and even during simple hypnosis without any thermal suggestions (Dikel and Olness, 1980; Lee and Olness, 1996). Other authors deny any possibility to increase body temperature with suggestions (Bregman and McAllister, 1985). The very few investigations on haemodynamics during hypnosis date back to years when high-level non-invasive instrumental procedures were not available (see for instance Clark and Forgione, 1974; Grabowska, 1970, 1971; Jana, 1967). Furthermore, they are not homogenous in methods, are often not reproducible, and mainly deal with the mere consequences of relaxation without taking into account specific intervention protocols. A systematic handling of this topic is therefore impossible, and in our knowledge the present study could be the first controlled clinical investigation in this field.

Although it is obviously impossible, up to date, to explain the results described herein from a pathophysiological point of view, one should accept the hypothesis suggested by many authors that the mental control of body temperature and its physical consequences are due to involvement of efferent sympathoneurons triggered by hypothalamic neurons interconnected to cortical, subcortical and limbic fibres (Muck-Weymann et al., 1997; Pearson and Hartley, 1957; Wallin, 1981). It has been demonstrated both via imaging and intracranial recording that during hypnosis there are changes in limbic structures including the amygdala and the hippocampus (De Benedittis and Sironi, 1988). A close linkage between simple relaxation and a sympathoadrenergic to vagohypotonic transition was hypothesized; nevertheless, the physiological content of the imagery amplifies the autonomic response (Kistler et al., 1999). Decreased amygdala activation during hypnotic stimuli might represent a cognitive reappraisal of emotional experiences. Unfortunately, the present paper was not conceived to furnish explanation to the observed phenomena. Future research would benefit from examining the interplay between thalamo-cortical and autonomic nervous system. The applicability of this hypothesis to the present study should be confirmed by neurophysiological evidences. Furthermore, this study does not allow to know whether subjects of a lesser hypnotic capacity would have the same hemodynamic response to thermal suggestions; it simply demonstrate that highly hypnotizable subjects can register changes compatible to real warming.

In conclusion, the possibility to control with hypnotic suggestions body temperature and haemodynamics is an indirect demonstration of mental control of arteriolar tone and suggest interesting applications, such as control of thermal dispersion, reperfusion of ischemic areas (for example in Raynaud's disease), improvement of cerebral circulation and selective kinetics of drugs.

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