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VASOMOTOR REACTIONS IN THE HYPNOTIC STATE *

BY

J. DOUPE, W. R. MILLER and W. K. KELLER

From the Research Unit, National Hospital, Queen Square, London

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IN 1935 Stürup, Bolton, Williams, and Carmichael reported that a painful stimulus (several pin-pricks) or a cold stimulus (small piece of ice) applied to the skin brought about a temporary vasoconstriction of the cutaneous blood-vessels. This vasomotor response could also be elicited by a deep inspiration or by a mental stimulus such as the solving of a mathematical problem or by a loud noise. It was shown that the vasoconstrictor response was dependent on the integrity of the sympathetic nervous system and was unaffected by lesions of the cerebral substance. The response had a latent period of 2–3 seconds and a duration of approximately 1 minute, and it was best demonstrated when the peripheral blood-vessels had been previously dilated by immersing an indifferent limb in water at 45° C.

The present paper reports the results of experiments to determine in what degree such a vasoconstrictor response is dependent on the “conscious” appreciation of the stimulus. In addition, the opportunity was taken to study the extent to which vasomotor activity could be influenced by suggestion in the hypnotic state.

Method

The changes in the volume of digits have been recorded photographically by the technique of Bolton, Carmichael, and Stürup (1936), who showed that the changes in volume were the result of active alterations in the vascular bed. By this method it was possible to record the changes in several digits simultaneously. The respiratory movements were registered on the same film by attaching another capsule to a balloon which was strapped to the chest wall.

In two highly suggestible subjects the state of the peripheral vessels was also followed by recording the skin temperature. This was obtained by small thermojunc-

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tions placed on the pads of the fingers. At the same time frequent readings of the rectal temperature were obtained by the use of a special thermojunction placed 5-6 cm. above the anal sphincter.

With minor alterations the same general procedure has been followed in all experiments. The subject, with his arms supported at the level of the heart, sat comfortably in a quiet, draught-free and dimly lit room, which was kept at a temperature of 22° to 24° C. The finger plethysmographs and respiratory balloon were attached and after a control period of 3 to 4 minutes the hypnotic state was induced. This was done by the customary method of optical fixation and suggestions of relaxation and sleep. Since the purpose of the hypnosis was to secure a loss of appreciation of pain, the report from the subject that he could not feel a deep pin-prick on an arm rendered analgesic under suggestion was used as the criterion of his co-operation and depth of the hypnosis.

As in most instances the cutaneous blood-vessels at the start of the experiment were in a constricted state, an attempt was made to bring about peripheral vasodilatation by suggesting to the subject that he was excessively warm. The subject's statement that he felt warm was used to confirm the efficiency of the suggestion. The feet were then placed in water at 45° C., to produce dilatation of the peripheral blood-vessels. This was done in order to compare changes in the peripheral vessels brought about by suggestion and by warming the body. Once dilatation of the finger vessels was produced by this immersion method, the vessels remained in a steady state of dilatation, giving a good base line from which to observe vasoconstriction. Still under hypnosis, one arm or one leg was rendered analgesic by suggestion. Pin-pricks were then applied alternately to the analgesic and normal limbs. Six to 40 stimuli were given on each side. To ensure that the pin-pricks were of equal intensity on each side, a pointed stylus was used. The stylus moved freely within a hollow needle and the strength of the stimulus was adjusted by attaching weights to the stylus and by altering the number of pin-pricks. The terms "moderate stimuli" and "severe stimuli" used below can only be defined as those stimuli which the subject in the waking state could bear with equanimity and those which he was hardly able to endure. The prolonged application of ice was used as the stimulus in some instances. At intervals the subject was told to take a deep breath or was given the suggestion that he felt pain. As at this stage of the experiment the cutaneous vessels were still in a dilated state, suggestions were given to the effect that the subject was extremely cold in an endeavour to produce a maintained peripheral vasoconstriction by this means. Before the hypnosis was terminated, suggestions of well-being and amnesia were given. After waking, the various stimuli were repeated. Further corroboration of the effectiveness of the hypnosis was then secured. This was judged by the lack of appreciation of the passage of the time and by the amnesia for the period of hypnosis.

The subjects of these experiments were four post-graduate students and four patients who had no evidence of organic disease of the nervous system.

Results

Effect of the hypnotic state on the peripheral vessels.—In 10 experiments the hypnotic state was induced while plethysmographic records were being taken. In none of these was there any change in the state of the peripheral vessels. In seven subjects the peripheral blood-vessels were in a constricted state at the beginning of the experiments and had not altered at the time deep hypnosis had been induced. Similarly, in the remaining three experiments in which hypnosis was induced with the vessels in a dilated state, no change in the vascular bed took place except for transient vasoconstrictions which occurred in association with several of the suggestions. A comparison of the size of the vasoconstrictor

responses in the waking state and in the hypnotic trance showed no significant differences. This was true whether the stimulus was a pin-prick or a deep breath.

Stimulation of areas of suggested analgesia.—In 11 experiments on five subjects one arm or leg was rendered analgesic by suggestion. In each experiment at least six stimuli were given to each side. In six experiments similar moderate pin-pricks to either arm caused almost similar degrees of vasoconstriction, and the values of P indicated that the differences observed in the individual experiments might well be due to chance (Table I). In one experiment, using stimuli of apparently moderate intensity, the average response to 11 paired stimuli was 37 per cent. less when the analgesic right leg was stimulated, and the small value of P showed that difference was significant (Table I, Subject A. B., Experiment 1). When the experiment was repeated with suggestion that the formerly normal left leg was not analgesic, greater constrictions were still obtained from stimulation of the left leg (Table I, Subject A. B., Experiment 2). The value of P, however, showed that this result was much less significant than the former, and it was explicable on the basis of persistence of the suggestion from the previous experiment. Disregarding these two results, the other experiments all showed a negative difference which, though separately of little significance, together implied that stimulation of the analgesic limb was slightly but definitely less effective in producing a vasoconstriction than similar stimulation of the normal limb.

In four experiments on two subjects very severe pin-pricks or the prolonged application of ice were used as stimuli. One subject (J. L.) on two previous occasions had shown nearly equal responses when subjected to moderate stimuli on the normal and the analgesic areas. Very strong stimulation of the normal limb on this subject produced a much more profound constriction than did similar stimulation of the analgesic area (Subject J. L., Table II). The other subject, who had once previously shown a positive difference and once a negative difference in response to moderate stimuli (Table I, Subject A. B., Experiments 1 and 2) was tested on three occasions with more severe stimuli. On one of these the responses were nearly equal (Table II, Experiment 4), while on two much greater responses were induced from the normal side (Table II, Experiments 3 and 5). It was learned from this subject that repeated reinforcement of the suggestion of analgesia was an important part of the technique (Table II, Subject A. B., Experiment 5). Eliminating the part of this experiment in which the suggestion was not being reinforced, the average of the percentage differences in responses was 27.1 per cent. with a severe stimuli, as compared to 12.1 per cent. which was the average percentage difference of the valid experiments with moderate stimuli.

In the instances where the hypnotic suggestion was most effective in inhibiting the response, it also altered its shape. Fig. 1, illustrating the responses to severe pin-prick, shows that although the vasoconstriction is less intense, its duration has not been shortened and that the main alteration is the abolition of the preliminary rapid diminution in volume.

TABLE I.—RESPONSES TO MODERATE STIMULI

(The figures represent the vertical distance in cm. between the diastolic phase of the pulse wave before and that during the time of greatest constriction as measure on the original record.)

SUBJECT	R. L.		A. R.		C. M.		J. L. (EXP. 1)		J. L. (EXP. 2)		A. B. (EXP. 1)		A. B. (EXP. 2)	
	NORMAL	ANAL- GESIC	NORMAL	ANAL- GESIC	NORMAL	ANAL- GESIC	NORMAL	ANAL- GESIC	NORMAL	ANAL- GESIC	NORMAL	ANAL- GESIC	NORMAL	ANAL- GESIC
	L. arm 1.9 2.9 1.3 1.0 0.9 1.0 1.7 1.6	R. arm 2.8 1.6 0.8 1.0 1.2 0.7 1.9	R. leg 2.7 1.7 5.0 3.7 3.8 2.0	L. leg 2.7 1.7 5.0 2.5 2.3 3.8	R. arm 1.0 0.6 0.5 1.0 0.8 0.5	L. arm 0.7 0.6 0.5 1.0 0.8 0.5	L. leg 1.6 1.2 2.1 1.0 2.8 2.9 2.2	R. leg 1.2 2.0 1.2 0.9 2.1 2.2 3.2	R. leg 2.5 1.5 3.0 2.9 5.5 5.0	L. leg 4.0 1.0 4.5 4.5 5.0 5.0	L. leg 2.5 0.0 2.7 2.8 3.2 4.6 2.5 2.0 3.1 3.8	R. leg 1.0 0.0 1.6 1.5 2.2 2.8 2.2 3.1 0.0 2.1 2.1	L. leg 0.0 0.0 0.6 0.2 0.5 1.7 0.9 1.5 0.4 0.3 1.0 6.0 0.8 1.0 1.6 7.0 3.8 0.8 6.0 1.79 +29.7% 0.5	L. leg 1.3 0.7 0.0 0.0 0.0 3.6 2.8 0.0 0.7 1.8 4.1 4.5 5.0 5.0 1.4 1.2 4.7 1.5 3.0 2.23
Mean	1.54	1.36	3.15	3.00	.75	.68	1.97	1.83	3.75	4.00	2.74	1.71	1.79	2.23
Difference	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P	0.6	0.6	0.8	0.8	0.6	0.6	0.9	0.9	0.8	0.8	0.02	0.02	0.5	0.5

P = Computed according to Mainland (1938) indicates the probability of the difference in means being significant. When P is 0.9 the difference might be expected in 9 out of 10 samples chosen from similar material. When P is 0.02 the difference would be expected to arise by chance only twice in 100 samples.

TABLE II.—RESPONSES TO SEVERE STIMULI
(Figures obtained as in Table I)

SUBJECT	J. L.		A. B. (EXP. 3)		A. B. (EXP. 4)				A. B. (EXP. 5)				
	NORMAL	ANAL- GESIC	NORMAL	ANAL- GESIC	NORMAL	ANAL- GESIC	NORMAL	ANAL- GESIC	(NO REINFCMT.)		(WITH REINFCMT.)		
									NORMAL	ANAL- GESIC			
	L. leg 3.0 3.2 3.0 3.5 3.2 1.7	R. leg 3.0 2.3 1.4 2.1 1.0 1.5	R. leg 5.0 5.0 5.0 1.0 4.5 4.1 3.8 2.3 2.1 0.0 4.0 1.0	L. leg 4.5 5.0 2.0 2.5 0.0 3.6 5.0 3.0 0.7 0.8 0.0 4.0	R. leg 4.0 3.3 2.2 1.1 1.9 4.4 2.3 2.2 2.6 2.8 0.4 1.5 3.2 2.3 4.0	L. leg 3.3 3.5 0.0 1.0 3.9 4.6 1.8 1.5 0.8 0.9 0.8 3.4 4.2 2.1 2.7 3.3 1.7 2.0 2.2 1.3 0.3 2.4 3.4	R. leg 2.3 1.6 0.8 4.8 0.7 1.2 0.8 2.0 2.1 0.0 3.2 4.6 2.2 1.4 4.0 4.1 8.0 1.8	L. leg 3.1 2.6 3.5 3.4 1.2 0.8 2.6 2.8 3.1 3.4 2.2 2.2 3.1 4.1 3.1 1.6 2.6 2.9 3.2	L. leg 1.3 0.6 1.2 6.0 2.8 1.5 2.1 3.4 0.0 0.8 3.6 1.4 4.0 4.1 8.0 1.8	R. leg 4.6 1.8 2.5 1.3 0.4 5.0 4.5 5.0 3.6 1.8 0.0 1.2 2.8 5.0 5.6	L. leg 3.3 2.5 4.6 5.0 4.7 7.0 7.5 4.7 2.2 3.7 4.7 3.6 — 4.1 2.3 2.8 8.0 3.2 2.0 4.0 0.8 1.4 5.4 4.0C — 2.5 — 3.92	R. leg 1.0 1.8 1.0 4.3 6.0 5.6 5.0 6.0 1.5 3.3 1.0 2.0 2.5 4.3 1.6 0.5 2.1 1.0 0.8 1.0 1.3 0.5 1.5 3.0 2.5B 2.3D 1.8 0.7 2.35	
Mean	2.93	1.88	3.18	2.62	—	—	2.31	2.19	2.64	2.99	—	3.92	0.7
Difference	—	—	—	—	—	—	—	—	+13.2%	—	—	—	2.35
P	0.02	35.8%	0.4	17.6%	—	—	0.6	0.6	0.6	0.6	—	—	40.0%

Responses indicated by letters are shown in Fig. 1.

The side from which the digital volume was being registered was of indifferent concern, as was shown in three experiments in which simultaneous records were obtained from the index fingers of both hands. In these cases stimuli on either arm produced the same amount of vasoconstriction in both digits.

Stimulation of the analgesic arm by many hard repeated pin-pricks caused no grimacing, although similar stimuli to the normal arm brought about this phenomenon. With the moderate stimulus ordinarily used no grimacing occurred. A slight alteration in respiratory rhythm was caused by stimuli applied to either side, but this tended to be greater when the normal side was stimulated. No significant changes in pulse rate were recorded.

Influence of suggestion on the state of the peripheral vessels.—Nine experi-

Fig. 1.—Record from right third finger during period of reinforcement. At A and C severe repeated pin-pricks were given to normal left leg. At B and D similar stimuli were given to analgesic right leg. Letters correspond to those in Table II, Subject A. B., Experiment 5, during reinforcement. R.F.3 is plethysmographic record of right third finger, the arrow pointing in direction of increase of volume. Downstroke in respiratory tracing is inspiration.

ments on seven subjects were performed in this series. When the subject was cold it was suggested to him that he was hot. This was continued for 10 minutes, and in eleven instances the subject reported that he felt warm. In no instance was there any change in digital volume. Sweating and flushing did not occur, although these were strongly suggested. The feet of the subject were then immersed in water at 45° C., which resulted in a marked increase in finger volume associated with flushing and sweating. Further suggestions of heat now brought about a temporary diminution in finger volume such as was seen with suggestions of many types. A feeling of intense cold was then induced by suggestion, but this caused no response except a temporary vasoconstriction. Despite the subjective evidence of the subjects, who stated that they felt very cold, none of the objective findings usually associated with this sensation were present. The peripheral vessels persisted in their dilated state; no shivering occurred and the skin remained flushed. The results of such an experiment on an extremely suggestible subject are illustrated in Fig. 2. As the room temperature was moderate and the rectal temperature was slowly falling, it is evident that the environmental conditions were not such as to over-rule any of the possible effects of suggestions of cold. Although the subject stated that he felt "cold through and through," no alteration in blood flow through the skin occurred as indicated by the steady skin temperature. When the legs were placed in water at 15° C. the subject, under the influence of suggestion, felt this water as distinctly hot. Nevertheless, the skin temperature fell as promptly as would that of the normal subject who could appreciate the coldness of the

water. It is of interest that during the immersion of the feet in cold water the rectal temperature was rising.

It has been reported above that the suggestion of cold caused a transient vasoconstriction of the peripheral blood-vessels. Similarly, the suggestion of a painful stimulus caused a vasoconstriction (Fig. 3). This response was easily

Fig. 2.—A : Hypnosis induced. B : Suggested cold for 9 minutes. C : Feet in hot water suggested cold. D : Feet in cold water, suggested hot.

and repeatedly elicited when the subject was hypnotized but in the normal state it tended to disappear after several repetitions of the suggestion.

Discussion

In presenting the above results it was first shown that the hypnotic state itself did not change the state of the peripheral circulation, nor did it significantly alter the vasoconstrictor response to a painful stimulus. Then it was shown that moderate pin-pricks applied to an area of induced analgesia produced a constriction of the peripheral vessels and that this vasoconstriction was slightly less than that caused by stimulation of an area of normal sensibility. When, however, a very strong stimulus was used, a much smaller vasoconstriction resulted from stimulation of the analgesic limb than from stimulation of the

normal limb. It was also pointed out that such semi-voluntary reactions as grimacing and alterations in respiratory rhythm were greater when the stimulus was applied to the normal side. Furthermore, a vasoconstriction followed mental activity and also the suggestion of pain in both the normal and the hypnotic states. No evidence was found that suggestions of warmth or coolness could modify the existing state of the digital circulation.

The finding of a diminished vasoconstrictor response from stimulation of an area of induced analgesia supports the work of several investigators who have used the psychogalvanic response (Moravesik, 1912 ; Georgi, 1921 ; Sears, 1932). On the other hand Peiper (1925), Prideaux (1926), and Levine (1930) were unable to find this difference in the psychogalvanic response. It is probable that this disparity might be explained by a difference in the stimuli employed. The present results indicate that when the stimulus is of light or moderate intensity it is more difficult to demonstrate that stimulation of an analgesic area produces a deficient vasomotor response. Furthermore, as

Fig. 3.—Record from third finger of left hand. At signal suggestion was given of pin-prick to right arm.

Levine points out, it is not easy to be sure that anaesthesia has actually been induced. For this reason more stress must be laid on the positive finding of a difference than on a negative result. The present results are in agreement with those of Marquis and Williams (1938) in so far as these authors showed that lesions of the nervous system which caused either a decrease or an increase in the appreciation of pain produced a like affect on the vasoconstrictor response. They found, however, that this correlation only held in subjects with lesions below the level of the thalamus. It is of interest, nevertheless, that the vasomotor responses that they measured were of the same order of magnitude as these elicited in this investigation from the anaesthetic side of hypnotized patients (Williams, 1938).

The different results produced by light and strong stimulation may be explained on the following basis, if it be granted that they were not due to inadequate hypnosis in the experiments with light stimuli. The results reported above show that the autonomic nervous system may be brought into activity by a noxious stimulus that is not consciously perceived and which apparently

does not set up any associated emotional state. It has also been shown that mental activity alone or in association with suggestions of pain will activate the autonomic nervous system so that a vasoconstriction of the peripheral blood-vessels ensues. The greater response which has been found on strongly stimulating the normal side may therefore be a summation of the results of the mental activity or emotional state caused by the appreciation of the pain, and of other more direct results of the stimulus. Conversely, the greater similarity of the responses following light stimulation of either side is due to the fact that the stimuli were too slight to cause much mental anxiety. Bearing these considerations in mind, it would seem that stimulation of an hypnotically anaesthetized area produces the same involuntary reactions as does stimulation of an area of normal sensibility, except for those elements which are contributed by the associated mental state. This suggestion is more or less in accord with Binswanger's (1908) conclusions in regard to the psychogalvanic reflex. He felt that only those mental activities and sensory perceptions that were associated with an emotional content had any influence on this reflex.

No evidence has been found that the state of the peripheral vessels could be altered by specific suggestion under hypnosis. This is supported by the results of Talbert *et al.* (1924), while the investigations of Hull and his colleagues (1932) tends to show that the less voluntary a function the less it is affected by suggestion. The only suggestions in the present work that were found to cause alterations in the state of the vessels contained ideas which might reasonably be thought to have induced an affective reaction in the subject. These negative results must be compared with the results of Hadfield (1917), who succeeded repeatedly in causing the formation of painful blisters in response to hypnotic suggestions. It is possible that his observation that suggestions of pain were essential for the successful production of blisters may be pertinent to this discussion. However, until more is known concerning this phenomenon, the present conclusions cannot be held to be incompatible with Hadfield's results.

In considering the fact that the vasomotor responses to stimuli applied to an area of suggested analgesia are deficient, it is relevant to point out the stage of cerebral activity which is interfered with by the suggestion. McDougal (1926) and others in experiments on specific object blindness have shown that the subjects retain a very high ability to discriminate the "unseen object" from closely similar objects. Pattie (1937), in an ingenious experiment in which he intertwined the arms so that the subject was unable to lateralise a stimulus correctly, showed clearly that hypnotic anaesthesia did not prevent the subject being conscious of a touch to the anaesthetic arm provided that he was unaware that the touch was actually on that arm. These observations indicate that the main effect of such suggestions of anaesthesia is to prevent the perception of the sensation by consciousness, despite the fact that complicated discriminatory processes are activated at the same time. These sub-conscious or co-conscious activities may be responsible for the small vasoconstriction which occurs in response to stimulation of an area of hypnotically induced anaesthesia. On the other hand, this residual response may be of the nature of a spinal reflex.

It remains to be considered whether the ordinary vasomotor response to a painful stimulus is dependent merely on the conscious perception of the stimulus or on the further elaboration of a feeling tone. Binswanger's views on the psychogalvanic response would support the latter alternative, as would the fact that stimuli which are of little emotional concern, such as light touch, rarely cause vasomotor response, although they reach a similar level of consciousness. However, Marquis and Williams (1938) reported that in subjects in whom lesions of the thalamus had caused hyperæsthesia the vasomotor responses from stimulation of the two sides of the body were equal despite an exaggerated emotional reaction when the hyperæsthetic side was stimulated. These results would apparently suggest that the emotional factor was unimportant, but it is difficult to be certain that an actual difference in the responses was not obscured by the method of analysis. Moreover, these authors draw attention to the problems of the exact significance of the emotional reaction in these subjects.

If it be true that the typical vasomotor response is dependent on the production of an affective reaction in the individual and if it be true that the vasomotor response following stimulation of an area of hypnotic analgesia is deficient because the knowledge of the sensation is not permitted to enter consciousness, it may be suggested that an emotional reaction is only engendered by those stimuli of which the subject is in some way aware.

Conclusions

The vasoconstriction of the digital vessels in response to a painful stimulus is partly dependent on the feeling tone associated with the awareness of the stimulus.

The state of the cutaneous blood-vessels cannot be altered by hypnotic suggestion, except in association with induced emotional states.

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