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Reduced felt arm sensation effects on visual adaptation

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Proprioception is often considered to be critically involved in producing adaptation to a prism-induced visual displacement. The present study focused on reduction of proprioceptive feedback during prism exposure by means of hypnotically induced anesthesia in the adapting arm. In addition, intermanual transfer was considered. Results showed adaptation occurring in situations where S could feel arm sensations while viewing arm movement during a prism exposure. However, if the adapting arm was hypnotically anesthetized while still remaining mobile, adaptation did not occur. No intermanual transfer was found between the adapted arm and the unadapted arm.

The usual explanation of adaptation to a prismatic displacement in an eye-hand coordination task has relied heavily upon the use of proprioceptive feedback, or information from the "position sense" (Harris, 1965; Hay & Pick, 1966). Harris (1965) felt that a person who watches his hand through prisms feels that hand to be in a position that differs from its actual location relative to the body. In such a situation, S's adapted hand comes to feel closer to or farther from his other hand than it really is. He referred to this situation as a proprioceptive shift.

Both McLaughlin and Rifkin (1965) and McLaughlin and Bower (1965) have extended Harris's (1963) data and have confirmed his predictions as to the way in which adaptation occurs to prismatic displacement. In these studies, S was required to point to a position which he felt was located straight ahead of his body position. Following prism exposure, it was found that location of straight ahead deviated from preexposure location of this point in space. In order to point accurately to the straight-ahead position, it is necessary that S be able to feel his arm with respect to its location in space and body position during the adaptation process. Thus, adapting to the straight-ahead position would require proprioceptive feedback.

Experiments which have involved felt, but not seen, arm movement during adaptation also imply that proprioception is more important than visual information in the adaptation process. McLaughlin, Rifkin, and Webster (1966) and Wallace (1972) found that Ss actively moving their nonvisible arms during prism exposure showed significant adaptation provided that a target line was included in the exposure background. These results were explained as due to a change in judgment of the direction of gaze. However, since S was able to adapt in the McLaughlin et al study, an alternative explanation might involve S's receiving proprioceptive feedback concerning his nonobservable arm location with respect to target location. Thus, S would feel his arm to be in a location to the right or left of its actual location with respect to the observable target location. This would produce a discrepancy in felt arm location with respect to actual target location. This discrepancy was considered necessary for adaptation to occur in a recent study by Melamed, Halay, and Gildow (1973), where S was required to track his moving arm with respect to a target location.

Hay and Pick (1966), in studying the effect of long-term exposure on the magnitude of the resulting adaptation, do not feel as strongly as Harris does that a proprioceptive shift is the essential modification during adaptation to prismatic displacement. They feel that the adaptation in the proprioceptive system is only transient and is succeeded by a stable adaptation in the visual system. However, whether one regards the proprioceptive shift as the essential modification during adaptation or as only a transient, its importance in the adaptation process is usually accepted (Epstein, 1967).

If proprioception does play a key role in the adaptation process, it would be interesting to consider the consequences of reducing or eliminating, as much as possible, the ability of S to feel or locate his adapting arm with regard to his own body position. This can be accomplished through a hypnotic induction procedure whereby S's adapting arm becomes anesthetized during prism exposure. Thus, if S's arm becomes anesthetic, even though S maintains the ability to control self-initiated motor movements, adaptation to prismatic displacement should differ from a situation where S can feel arm sensations and position with respect to body position. The present study provides a test of the effect of hypnotically induced anesthesia on subsequent adaptation to prism displacement. In addition, the present study considers intermanual transfer from the adapting arm to the nonadapting arm. Since intermanual transfer has been found occurring in an eye-hand coordination task by some investigators (Kalil & Freedman, 1966) and not by others (Harris, 1963), no prediction is made concerning intermanual transfer in the present study.

METHOD

Subjects

Thirty right-handed undergraduate volunteers from the

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introductory psychology sections at Western Illinois University were selected as Ss. Before participating in the present study, all Ss had previously taken the Harvard Group Scale of Hypnotic Susceptibility (Shor & Orne, 1962) as part of a mass testing session. Fifteen Ss scored between 0 and 2 on the Harvard Scale, and the other half of the Ss scored between 10 and 12. In addition, only Ss who did not wear corrective glasses could volunteer for experimental participation.

Apparatus

The Ss were seated at a small wooden table with their heads securely positioned in a combination head- and chinrest. Throughout all experimental conditions, Ss wore Risley rotating prisms over both eyes attached to the front surface of welder's goggles. In front of S on the table was a rectangular wooden box, 50.0 x 75.0 cm, open on the side facing S. When S was asked to observe movements of his hand, it was placed in an aluminum holder running on an aluminum track on the top level of the wooden box. Immediately behind the track was a wooden backboard that extended the entire width of the box. A tagboard with one target (0.5 x 16 cm) was placed over the backboard for the entire experiment. The target was located symmetrically with respect to S's body position. During pre- and postexposure tests, S's hand was kept out of sight by placing it in a holder on an aluminum slide in the lower compartment (interior) of the box. The slide was found directly below the one on the upper level of the box. The location of S's judgment of the target line was determined by reading a value from a measuring stick that was attacked to the interior slide and which was, thus, moved with it.

Design

The primary factor in this design was whether Ss were or were not hypnotized during prism exposures. Fifteen Ss were assigned to each group as a function of their prejudged susceptibility to hypnosis. High-susceptibility Ss were hypnotized. Low-susceptibility Ss were asked to simulate the hypnotic condition. Each susceptibility group was subdivided, with 8 of the 15 Ss receiving the two experimental conditions in the following order: adaptation under anesthesia during initial prism exposure followed by normal, proprioceptive feedback during the subsequent prism exposure. For the remaining Ss, the order of the experimental conditions was reversed. The term "anesthesia" in the present study refers to a hypnotic, instructional condition where loss of any sense of arm location other than visual occurs.

Procedure

Ss were tested individually with their heads securely positioned in a combination head- and chinrest attached to the experimental apparatus. The procedure consisted of the following five conditions, before and after which each S was required to perform a nose-touch task with his right index finger and with his eyes closed to assure proprioceptive accuracy in locating the nose.

Preexposure 1

To establish baseline estimates for the right hand, all Ss were required to place their unobservable, right index fingers in an aluminum holder affixed to the bottom slide of the apparatus. They were then to point to the location of the test target five times by moving the slide from outside the visual field towards the target until they felt their fingers to be in alignment with it. The Risley prisms were set to 0 diopter for this condition. Following this session, the same procedure was also used to establish baseline estimates with the unobservable, left index finger.

Exposure 1

Following baseline estimates of target location, half of the Ss scoring high in hypnotic susceptibility received a hypnotic induction procedure with a suggestion of relaxation; the other high-susceptibility Ss were given hypnotic induction and were also given the suggestion that their right arms would be absent of all sensations, although they would still be able to move and control their observable right arms. Ss judged low in susceptibility, and thus not hypnotizable, participated in the same hypnotic induction procedure as hypnosis Ss, except that each half of this group was instructed to simulate one of the two experimental conditions of relaxation and anesthesia. These Ss were instructed as to consequences of hypnotic induction prior to simulation, and thus were able to approximate these hypnotic states. Following hypnosis induction (actual or simulated), the prisms were set to 20 diopter, base left, and the Ss were required to observe active, visible movement of the right arm in the top level of the apparatus for a total of 15 min. The rate of lateral movement was regulated by a metronome set so that one movement cycle occurred in each 6-sec period.

Postexposure 1

Following prism exposure, S was returned to his preexposure normal state of consciousness, as measured by the ability of S to accurately perform the nose-touch task, and his right arm was returned to the bottom slide. Prisms were also set to 0 diopter. Thus, the procedure in Postexposure 1 was the same as in Preexposure 1 for both the right and left index fingers, tested in that order. With this procedure, intermanual transfer could be tested.

Exposure 2

A second exposure condition was then introduced, where S again was required to observe lateral right-arm movement under a 20-diopter, base left prism shift for 15 min, as in Exposure 1. Within each group of Ss, the conditions of Exposure 1 were reversed for Exposure 2. Ss observed arm movement during this condition. Again, Ss high in hypnosis susceptibility performed this task under hypnosis, and the remaining Ss were again asked to simulate as much as possible a state of hypnosis during the prism exposure. Thus, anesthesia (actual or simulated) was counterbalanced with normal proprioceptive feedback in Exposure 1 and Exposure 2.

Postexposure 2

Following Exposure 2, S was again returned to the preexposure conditions. Once again, the ability of S to align his unobservable index fingers with a target in his visual field was tested, first with the right and then with the left hand.

The checks for hypnosis induction were the hand clasp and arm rigidity. For Ss in the high-hypnosis-susceptibility group, S's arm was deemed sufficiently anesthetized if he failed to respond to being pinched in his arm, shoulder, hand, and fingers. In addition, S was required to close his eyes and to try to touch the tip of his nose with his right index finger. Sufficiently anesthetized Ss could *not* perform this proprioceptive task. The magnitude of S's error in trying to locate his nose with his right index finger under hypnosis anesthesia ranged between 5 and 13 cm from actual nose-finger congruency. Error in reaching for the nose in nonanesthetized Ss was nonexistent.

RESULTS

Analyses of variance were performed on the data of the present study. Individual Newman-Keuls analyses

Table 1
Arm Movement Displacement and Difference Aftereffects Averaged Over Presentation Orders

Group		Preexposure 1		Anesthetic Instructions		Relaxation Instructions	
		Mean*	SD	Mean	SD	Mean	SD
High Hypnosis Susceptibility	Right Arm	0.1 Deg	0.0	0.6 Deg	0.2	2.6 Deg†	0.6
	Left Arm	4.7 Deg	1.3	0.2 Deg	0.0	−1.2 Deg	0.3
Low Hypnosis Susceptibility	Right Arm	−0.1 Deg	0.1	3.5 Deg†	0.9	3.2 Deg†	1.0
	Left Arm	4.3 Deg	1.0	0.9 Deg	0.1	0.5 Deg	0.1

**Deviation from actual target location where 0.0 deg represents target position. A positive deviation represents pointing to the right of actual target location, whereas a negative deviation indicates pointing to the left of the target.*
†$p < .001$

were done within each experimental condition to analyze for order effects. Since none of the order effects were significant, the rest of the analyses reported here were averaged over the two different orders.

The first analysis was concerned with high or low susceptibility to hypnosis as a between-S variable and arm used in pointing to targets (left and right) as a within-S variable. In this analysis, the dependent measure was the placement of S's index finger with respect to target location in the visual field in Preexposure 1. No significant difference was found between the two groups of Ss in this baseline estimate of target location [$F(1,28) = 0.32$]. However, a difference was found between alignment of the right index finger vs the left index finger with respect to target location [$F(1,28) = 58.30$, $p < .001$]. The interaction of hypnosis susceptibility with arm used in pointing was not significant. The means of baseline alignment locations are found in Table 1.

The second analysis concerned the effects of anesthesia, whether actual for Ss high in hypnosis susceptibility or simulated for Ss in the low-hypnosis-susceptibility category, upon adaptation (the difference in Preexposure 1 and both Postexposure 1 and Postexposure 2, averaged over the different orders). For the high-hypnosis-susceptibility group, a mean aftereffect of 0.6 deg in the direction opposite the prism displacement was found when S pointed to the target with the right adapted arm. For the low-hypnosis-susceptibility group with simulated anesthesia (no hypnosis) and where S could still feel right arm sensations, the aftereffect was 3.5 deg. Using a two-tailed t test, only the latter aftereffect was found to be significantly different from zero [$t(14) = 5.71$, $p < .001$]. The difference in produced aftereffects in the two groups was also significant [$F(1,28) = 5.72$, $p < .02$]. Mean aftereffects found with the nonadapted left arm for Ss high in hypnosis susceptibility and those low in such susceptibility were 0.2 and 0.9 deg, respectively. Using a two-tailed t test for correlated measures, neither of these was found to be significantly different from zero.

The third analysis compared the aftereffects produced by anesthetic or relaxation instructions (again averaged over the two different orders). In the high-hypnosis-susceptibility group under relaxation instructions during prism exposure, a mean aftereffect of 2.6 deg was found. For the group low in hypnosis susceptibility under relaxation instructions, a mean aftereffect of 3.2 deg was found. Using a two-tailed t test, both aftereffects were found to be significantly different from zero at $p < .001$. The difference between these aftereffects was not significant [$F(1,28) = 1.04$].

To analyze intermanual transfer, the difference in preexposure and postexposure movements were averaged over the different orders of presentation and over the anesthetic or relaxation instructions. Aftereffects with the left nonadapted arm for hypnotized and nonhypnotized Ss were −1.2 and 0.5 deg, respectively. A two-tailed t test for correlated measures showed neither of these to be significantly different from zero.

The final analysis was concerned with the effect of anesthesia instructions compared within each type of consciousness condition. For Ss low in hypnosis susceptibility, the magnitude of the aftereffect produced by the adapted right arm with anesthetic instructions (3.5 deg) was not significantly different from the effect with relaxation instructions (3.2 deg). This was also the case for the same comparisons made for the low-hypnosis-susceptibility group with the nonadapted arm (0.9 vs 0.5 deg). A significant difference, however, was found in themagnitude of the effect within the high-hypnosis-susceptibility group receiving anesthetic instructions (0.6 deg) compared to 2.6 deg with relaxation instructions (Newman-Keuls, $p < .05$). Nonadapted arm aftereffects for this group of Ss were 0.2 vs −1.2 deg for the anesthetic instruction condition and relaxation instruction condition, respectively.

DISCUSSION

Harris (1965) feels that rapid adaptation to a displaced visual field involves a change in the felt position of the arm relative to the body. The results of the present study seem to support his hypothesis. When Ss were allowed to observe and feel arm movement during prism exposure, significant adaptation in the form of negative aftereffects resulted. However, if Ss could not feel arm movement, adaptation was minimal and not significantly different from zero. Since only the adaptation of hypnotized, anesthetic Ss was significantly different from the other Ss' adaptation, and since hypnosis without anesthesia had no significant effect, hypnosis alone could not account for the observed differences. These Ss' failure to be able to perform the nose-pointing task also suggests that the anesthesia considerably reduced proprioceptive feedback with regard to locating the arm with respect to parts of the body.

Harris (1963), in an eye-hand coordination task where adaptation was tested for in the adapted and nonadapted arm, reported adaptation to be significant only in the adapted hand. Thus, no intermanual transfer was found. This finding is also reported by Hamilton (1964) as long as Ss were not allowed to move their heads during prism exposure. If Ss were allowed to move their heads, intermanual transfer did occur. The present study, which required Ss to keep their heads stationary during prism exposure, agrees with previous findings and concludes that short-term adaptation under these conditions is adapted-arm specific.

In the preexposure portion of the present study, a difference was found between pointing accuracy to the visual target with the right arm compared to the left arm. Since all Ss were right-arm dominant, it is not surprising that accuracy of pointing to targets in the preexposure condition varied with arm used for pointing. Whether or not this baseline effect existed in previous studies (Harris, 1963; Hamilton, 1964) could not be determined, since what is typically reported are simply the difference scores between the pre- and postexposure arm locations with respect to targets.

In summary, if Ss cannot feel arm movement during prism exposure, adaptation to a visual displacement does not occur. Thus, proprioception and resultant feedback with respect to body part location is an essential component of adaptation to a short-term prism exposure. The importance of visual adaptation in long-term exposures, studied by Hay and Pick (1966), could not be assessed by the results of the present study and should be further investigated.

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