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Further evidence for dissociating decay and readaptation in prism adaptation

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Two readaptation procedures and a decay procedure were compared for their effectiveness in reducing prism aftereffects. Following a proprioceptive readaptation procedure (searching with the previously adapted hand for a peg held by the previously nonadapted hand), both the target-pointing and proprioceptive shift measures showed significant readaptation, yielding final aftereffects that were not significantly different from zero. Following an active readaptation procedure (repeating the exposure task under normal vision), congruence between the target-pointing and proprioceptive measures was also obtained, as neither measure showed significant readaptation. Such congruence, however, was not obtained for the decay condition, in which significant readaptation was obtained for the target-pointing measure but not for the proprioceptive measure. These data provide further support for Melamed, Moore, and Beckett's (1979) conclusion that readaptation and decay lead to distinguishable processes and indicate that changes in the proprioceptive localization of the adapted arm underlie the readaptation that occurred in the proprioceptive readaptation condition.

Readaptation concerns the extent to which an observer who has adapted to prismatically displaced vision regains his or her normal, preexisting visual-motor coordination. Based on the assumption that the "normal" preadaptation state is itself a state of adaptation (Ebenholtz, 1968), procedures that are effective in producing original prism adaptation should be more effective than the simple passage of time in returning the subject to his or her original preadapted state under normal vision. To test this assumption, Melamed, Moore, and Beckett (1979) compared two readaptation procedures and four decay procedures for their effectiveness in reducing aftereffects resulting from exposure to prismatically displaced vision. Their results indicated that while all the groups except one decay condition showed significant reductions in prism aftereffects, only the two readaptation procedures resulted in final aftereffects that were not significantly different from zero. The two readaptation procedures involved subjects' observing their own active arm movements under normal vision (active group) and searching, while blindfolded, with their previously adapted hand for a peg held underneath and wiggled by their previously nonadapted hand (Proprioceptive 1 group).

The fact that both readaptation groups showed strong readaptation that was greater than any of the decay groups was interpreted as supporting the information discordance hypothesis (Wallach, 1968). In other words, readaptation, as well as adaptation, involves the integration of discordant sensory information regarding the location of the arm. Furthermore, since both the active condition, which involved a visual-proprioceptive discrepancy, and the Proprioceptive 1 condition, which involved a proprioceptive-proprioceptive discrepancy, yielded equivalent amounts of readaptation, Melamed, Moore, and Beckett (1979) interpreted their results as suggesting a proprioceptive locus for the adaptation that had been produced. This interpretation is also supported by the fact that Melamed, Moore, and Beckett used a Held-type exposure procedure, since a number of investigators (e.g., Choe & Welch, 1974; Cohen, 1967; Redding & Wallace, 1976; Uhlarik & Cannon, 1971) have reported results suggesting that such a procedure leads to adaptation that is based primarily on changes in the proprioceptive localization of the adapted arm. Unfortunately, however, since Melamed, Moore, and Beckett did not include in their study a direct measure of changes in the proprioceptive localization of the adapted arm, this conclusion must be viewed as tentative.

The purpose of the present study was twofold. First, it was an attempt to replicate the results of the readaptation conditions obtained by Melamed, Moore, and Beckett (1979). Second, and more important, by including a direct measure of proprioceptive localization for the exposed hand, it was an attempt to directly verify

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whether the adaptation obtained was in fact based on a change in the proprioceptive localization of the exposed hand and to determine how such proprioceptive changes were affected by the readaptation procedures.

METHOD

Subjects

The subjects were 36 right-handed females recruited from introductory psychology sections at Kent State University. The subjects received course credit for participating. Only subjects who did not wear corrective glasses were selected.

Apparatus

The apparatus used in this experiment was the one described in detail in Melamed, Moore, and Beckett (1979).

Design and Procedure

A 3 by 2 by 2 mixed design was used. The three readaptation and decay procedures (proprioceptive, active, and dark) constituted the between-subjects variable. Twelve subjects were randomly assigned to each of the resulting groups. The within-subjects variables were measures of adaptation (target-pointing shift or proprioceptive shift) and the postexposure test period (first or second). All prism viewing was binocular, with the prisms oriented base left. All subjects went through a pretest period, during which measures of hand positioning and target-pointing accuracy were obtained with the prisms set at 0 diopters. The hand-positioning task involved the subject's pointing straight ahead of her nose with her eyes closed. The target-pointing task involved the subject's pointing, without sight of her hand, at each of the three target lines, which were 5 cm apart and centered on the backboard of the apparatus. Nine target-pointing trials (three for each of the three target lines) and nine hand-positioning trials were run; the order of the trials was randomized for each subject. The pretest period was followed by a 10-min exposure condition that was the same for all subjects. Exposure consisted of the subject's viewing her own active arm movements while wearing 20-diopter prisms. The subject's hand movements were confined to the visual field and were paced by the beat of a metronome. At the end of the exposure period, the prisms were reset to 0 diopters, and the first posttest period was immediately begun. This consisted of tests of hand positioning and target pointing performed in the same manner as during the pretest period.

Immediately after the first posttest period, the subjects were assigned to one of the three readaptation/decay conditions. Subjects assigned to the active group performed the same task as in the initial exposure condition (i.e., they observed their own active arm movements, but now under normal vision). Subjects in the proprioceptive group were blindfolded and instructed to search with the previously exposed (i.e., right) hand for the peg held underneath and wiggled by the previously unexposed hand. The previously unexposed (left) hand was randomly placed by the experimenter on the underneath side of one of the seven pegs arranged in a semicircular arc in front of the subject. After the subject found the correct peg, another trial began. The proprioceptive group was thus the same as the proprioceptive 1 group in Melamed, Moore, and Beckett (1979). The subjects in the dark group sat in the dark with their hands separately positioned on a pillow in their laps while their heads remained fixed. This group represents the absolute or prototypical decay condition. Each of the three procedures just described lasted 10 min and was immediately followed by a second posttest period. This second posttest period was identical to the pretest and first posttest periods, consisting of hand-positioning and target-pointing trials.

RESULTS

Magnitude of adaptation following the exposure and readaptation/decay procedures was calculated by subtracting the mean pretest setting for a given type of test trial from the corresponding mean setting from each of the two posttest periods. Proprioceptive shift and target-pointing shift thus represent, respectively, changes on the hand-positioning task and the target-pointing task. For purposes of analysis, these aftereffects were considered positive when they were in the direction of the prism base. The significance of these aftereffects, which are presented in Table 1 separately for each group, were evaluated using two-tailed t tests for correlated measures.

As expected, all three groups showed significant target-pointing and proprioceptive shifts during the first posttest period. Furthermore, only the proprioceptive group failed to show significant aftereffects for either measure during the second posttest period. A mixed design (groups by measure by tests) analysis of variance performed on these data yielded significant effects for groups [$F(2,33) = 4.395$, $p < .025$], tests [$F(1,33) = 42.355$, $p < .001$], Groups by Tests [$F(2,33) = 5.367$, $p < .01$], Measures by Tests [$F(1,33) = 47.748$, $p < .001$, and Groups by Measures by Tests [$F(2,33) = 3.898$, $p < .05$]. Given the significant three-way interaction, tests of simple main effects were performed for each factor over the levels defined by the combination of the other two factors. In evaluating the groups factor, no significant differences between groups were obtained for either the target-pointing [$F(2,132) = .464$] or the proprioceptive measure [$F(2,132) = 2.394$] during the first posttest period, whereas during the second posttest period, significant differences were obtained for both the target-pointing [$F(2,132) = 6.142$, $p < .005$] and the proprioceptive [$F(2,132) = 8.325$, $p < .001$] measures. Newman-Keuls analyses further indicated that during the second posttest period, the dark and active groups yielded equivalent aftereffects that were significantly larger than those shown by the proprioceptive group. Analysis of the measures factor indicated that the only difference between the target-pointing and proprioceptive measures that reached significance was in the proprioceptive group during the first posttest period

Table 1
Mean Aftereffects in Degrees

	Measure of Adaptation					
	Proprioceptive Group		Active Group		Dark Group	
Posttest	T	P	T	P	T	P
1	4.12*	2.37†	3.82*	3.40*	4.45*	3.76*
2	.79	.71	3.00*	2.81*	2.48*	3.21*

Note—*T = target pointing; P = proprioceptive shift.*
**p < .01.* †*p < .05.*

[F(1,66) = 18.790, p < .001]. Finally, separate analyses of the test factor for each measure and group indicated that the proprioceptive group showed significant readaptation for both the target-pointing [F(1,66) = 56.973, p < .001] and proprioceptive [F(1,66) = 14.689, p < .001] measures and the dark group showed significant readaptation for the target-pointing measure [F(1,66) = 20.003, p < .001]. Both measures in the active group and the proprioceptive measure in the dark group failed to yield significant differences between the first and second posttest periods.

DISCUSSION

The results obtained for the proprioceptive and dark groups were in direct agreement with those reported by Melamed, Moore, and Beckett (1979) and support the view that decay and readaptation procedures lead to distinguishable processes. While both groups yielded a significant reduction in target-pointing aftereffects, only the proprioceptive group yielded final aftereffects that were not significantly different from zero. The addition of a measure of proprioceptive shift in the present study further showed that it was in fact the proprioceptive localization of the adapted hand that was affected by the proprioceptive readaptation procedure. The proprioceptive shift measure was reduced to the extent of being nonsignificant in the proprioceptive group, whereas the dark group showed no significant decay of proprioceptive shift and thus yielded a significant proprioceptive shift during the second posttest period. Using a similar Held-type adaptation-induction procedure, Redding and Wallace (1976) showed that at the end of a 30-minute dark decay procedure, significant adaptive proprioceptive shift was still observed, although substantial decay of proprioceptive shift did occur during the decay period.

The main difference between the present results and those of Melamed, Moore, and Beckett (1979) was that in the present study, the active readaptation group failed to show significant readaptation, whereas Melamed, Moore, and Beckett's readaptation group showed significant readaptation to the extent that the final target-pointing aftereffects were not significantly different from zero. The performance of the subjects in the active group in the present study is reminiscent of those in the "move" control condition used by Melamed, Moore, and Beckett. This procedure involved blindfolded subjects moving their adapted hands back and forth through the same movement limits as the active readaptation group. The procedure yielded the same results as were obtained for the active readaptation group in the present experiment (i.e., no reduction in aftereffects from the first to the second posttest periods). The data for the active readaptation group in the present study perhaps further emphasize and expand on the issue of the attentional requirements of the various adaptation-induction procedures previously raised by Melamed, Halay, and Gildow (1973) and Melamed, Wallace, and Seyfried (1979). Both Melamed et al. (1973) and Melamed, Wallace, and Seyfried (1979) showed that manipulations that increase the likelihood of the subjects' attending to arm location in a Held-type adaptation procedure increase the magnitude of adaptation observed. It would not seem unreasonable to suggest that the same holds true for readaptation. Apparently, our active group was not actively paying attention to or processing the visual information present concerning hand location during the readaptation interval. It is interesting that neither the pointing behavior nor the proprioceptive positioning showed significant readaptation. The data for these two response systems were as congruent here as they were for the proprioceptive group, which was not the case for the decay group.

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