An examination of the relationship between visual capture and prism adaptation

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The phenomena of prismatically induced "visual capture" and adaptation of the hand were compared. In Experiment 1, it was demonstrated that when the subject's hand was transported for him by the experimenter (passive movement) immediately preceding the measure of visual capture, the magnitude of the immediate shift in felt limb position (visual capture) was enhanced relative to when the subject moved the hand himself (active movement). In Experiment 2, where the dependent measure was adaptation of the prism-exposed hand, the opposite effect was produced by the active/passive manipulation. It appears, then, that different processes operate to produce visual capture and adaptation. It was speculated that visual capture represents an immediate weighting of visual over proprioceptive input as a result of the greater precision of vision and/or the subject's tendency to direct his attention more heavily to this modality. In contrast, prism adaptation is probably a recalibration of felt limb position in the direction of vision, induced by the presence of a registered discordance between visual and proprioceptive inputs.

Since the pioneering studies of Helmholtz (1925, pp. 246-247) and Stratton (1896, 1897a, 1897b), it has generally been agreed that much can be learned about perception and perceptual-motor coordination by noting the response of human subjects to optically induced visual distortion. (See Kornheiser, 1976, and Welch, 1974, 1978, for reviews of the extensive literature in this area.) The most commonly used visual rearrangement is 11° lateral displacement, effected by a 20-diopter wedge prism. Viewing the stationary hand through this device results in a discrepancy between visual and proprioceptive stimuli, an intersensory discordance which, however, undergoes an immediate and nearly complete perceptual resolution in favor of vision. In short, the hand instantly feels as if it is located near its displaced optical position. Thus, in some manner, the subject, when confronted with conflicting inputs from eye and hand, weights the former much more heavily in his ultimate localization of the limb. This relative dominance of vision over the sense of felt limb position¹ is referred to as "visual capture" (Hay,

Pick, & Ikeda, 1965; Tastevin, 1937).² When the subject closes his eyes, the change in felt limb position dissipates very rapidly, perhaps in a few seconds (Hay et al., 1965). Thus, two distinguishing characteristics of visual capture are that (1) it attains its greatest strength immediately after the limb is first seen through the prism and (2) it disappears several seconds after vision is precluded.

Two explanations for the phenomenon of visual capture have been offered. The first of these is that vision is given greater weight than the limb-position sense because vision is much more *precise* (i.e., less variable in its accuracy from moment to moment). This may be referred to as the modality precision hypothesis. The second (although not necessarily mutually exclusive) proposal is that visual capture results from the fact that visual inputs are typically more salient than proprioceptive-kinesthetic inputs, or at least more closely attended (e.g., Canon, 1970, 1971). This has been termed the directed-attention hypothesis. With respect to the latter hypothesis, Posner, Nissen, and Klein (1976) have argued convincingly that vision is actually *less* automatically attention-eliciting (i.e., salient) than are the other spatial modalities and that it is because of this deficiency that human subjects are predisposed to pay special attention to visual inputs. Thus, it does not appear to be the case that the relative precision of the various spatial sensory modalities is perfectly correlated with their relative salience, although it

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is possible that the more precise the modality, the more attention is *directed* by the observer toward it. In short, the potential relationship between the precision, salience, and degree of directed attention characteristic of the various sensory modalities, as well as the implications of this relationship for visual capture, remains unclear.

Visual capture is elicited in situations in which the subject views momentarily his prismatically displaced and stationary hand. If, instead, he is allowed to observe the limb through the prism for a more extended period while moving it about, the resulting change in its felt position is imbued with increased longevity and is referred to as prism adaptation. Choe and Welch (1974), for example, obtained a prism-induced position sense shift which persisted for at least 25 min after the prisms were removed. Naturally, the subject was not allowed to see his hand during the postexposure period. Direct evidence for this more enduring recalibration of felt limb position is seen in the fact that after removal of the prisms the subject, with eyes closed, will misplace his previously prism-exposed hand when attempting to point straight ahead of his nose (e.g., Harris, 1963). A number of investigators (e.g., Hamilton, 1964; Harris, 1965) have concluded that this shift in felt limb-position sense is the primary basis for both the prism-adaptive eye-hand correction that occurs during prism exposure and the initial misreaching after removing the prism (the "negative aftereffect"). Other forms of prism exposure may produce shifts in apparent visual direction, generally considered to be the result of changes in felt position of the eyes or head (e.g., Craske, 1967; Harris, 1965). However, such "visual" prism adaptation is not the concern of the present paper.

Because both visual capture and visuomotor prism adaptation are induced by prismatic exposure of the hand and result in a shift in the felt position of this limb, it is not surprising that some investigators (e.g., Hay et al., 1965; Kelso, Cook, Olson, & Epstein, 1975) have assumed or implied that the underlying processes are similar or identical. However, there are some differences between the two phenomena that should be considered before accepting this conclusion. First, while visual capture reaches full strength as soon as the observer is allowed to see his prismatically displaced limb, adaptation is acquired much more gradually, not reaching its maximum level until after 15-20 min of exposure under some conditions (e.g., Efstathiou, 1969). Second, visual capture declines to zero in a matter of seconds, whereas prism adaptation persists for an extended period of time after the hand has been hidden from view (e.g., Choe & Welch, 1974).

An important characteristic of prism adaptation is that, for its production, it requires, or is greatly facilitated by, active limb movement. The classic demonstration of this fact was by Held and Hein

(1958), who found that viewing the actively swinging, prismatically displaced hand led to significant adaptation, whereas exposure to the same form of limb movement effected by external means failed to produce any adaptation at all. Although no previous experiment has directly examined the active/passive manipulation as it might affect visual capture, there is some suggestive cross-experiment evidence. In most of the early work on visual capture (e.g., Hay et al., 1965; Pick, Warren, & Hay, 1969) the subject's to-be-exposed limb was placed into position by the experimenter (immediately prior to prism exposure). This form of passive exposure led to very significant visual capture (as much as 80% of the theoretical maximum). However, in a later experiment by Warren and Cleaves (1971), the "target" hand was actively placed into position by the subject before its exposure and the visual capture obtained (with 10° displacement) amounted to less than 40°. Thus, although there were a number of other differences between the Warren and Cleaves experiment and previous investigations of visual capture, it is suggested that active limb movement may actually retard capture, just the opposite of its effect on prism adaptation. If verified, this finding would support the existence of different underlying processes for the two perceptual events. It might be proposed, for example, that visual capture represents a tendency for vision to be weighted heavily over felt limb position because, typically, the latter is much less precise, salient, or attended. In contrast, adaptation may be a semipermanent *recalibration* of felt limb position which requires for its activation the more marked discordance between visual and limb position inputs that results when limb movement is actively instigated. Indeed, Paillard and Brouchon (1968) demonstrated that when the limb is moved actively, its felt position is more precise (and perhaps more intensely attended as well) than when it is moved passively. Therefore, it might be argued that active limb movement, by its effect on felt limb position, causes an increase in the registered discordance between felt and seen limb, thereby decreasing the dominance of vision (visual capture) and increasing adaptation. It was the aim of the present investigation to test this hypothesis.

Two experiments were conducted. In the first, visual capture was measured under conditions of either active or passive limb movement. The second experiment represented a within-subject verification that the active/passive manipulation used here had the traditional effect on visuomotor prism adaptation.

EXPERIMENT 1

Method

Subjects. Twelve voluntary subjects from introductory psychology classes at the University of California, Riverside, each served in active and passive limb movement conditions. The eight

males and four females were all right-handed, possessed normal vision (in some cases corrected), and were naive to the purpose of the experiment.

Measures of visual capture and adaptation. Visual capture was measured in the fashion introduced by Hay et al. (1965). In brief, the measure represents the immediate shift in the felt position of the visible, prismatically displaced left index finger taken as a proportion of the total discrepancy between visual and proprioceptive inputs. To obtain this proportion, it was necessary to take three perceptual measures. First, with the left arm extended away from his body and resting upon a raised table top, the subject indicated the place in which he felt his left index finger was located by reaching under the table with his unseen right hand. The subject's view was obscured by means of a shutter, thereby forcing him to make his judgement entirely on the basis of proprioceptive input from the left arm. This was referred to as the proprioceptive control (P_c) measure. Naturally, the felt position of the pointing arm, as well as the subject's ability to coordinate this limb, were also involved in his judgement. However, as will be seen below, all of the subject's perceptual tasks involved the use of the right arm, and therefore these factors were presumably held constant. The subject's second task was to look through a 20-diopter base-left prism, which produced an 11° rightward optical displacement, and to point beneath the table at each of the three targets with the unseen right hand. This task assessed the apparent visual locus of objects (other than the body) when viewed through the prism. This was referred to as the visual control (V_c) measure. Thus, the difference between P_c and V_c measures represents the effective prismatic displacement of the hand as experienced by the subject. Finally, the subject was allowed to view his prismatically displaced left index finger and hand resting upon the far edge of the table top. Immediately upon seeing the limb, the subject was to reach beneath the table and to place his nonvisible right index finger directly beneath the *felt* location of his visible left index finger. He was explicitly instructed to keep his eyes open but to ignore the apparent visual position of the target finger when pointing. Thus, this task involved a state of sensory discordance between felt and seen limb position and was referred to as the proprioception-vision (PV) measure. It was in this situation that visual capture could occur. Visual capture was indexed by the following ratio: $(P_c - PV)/(P_c - V_c)$. The denominator of this fraction represents the experienced proprioception-vision discrepancy; the numerator represents the shift in felt limb position induced by the prismatic view of the limb. If, during the PV measures, the subject pointed at the visual image of the finger when asked to indicate its felt position, the numerator would equal the denominator, leading to a ratio of 1.0, indicative of complete visual capture. Alternatively, pointing at the finger during the PV measures with the same accuracy as when it was unseen (i.e., on the P_c trials) would produce a numerator of 0 and, therefore, a ratio of 0, signifying the absence of visual capture. Ratios falling somewhere between 0 and 1.0 denote incomplete capture.

Although Experiment 1 was designed to produce visual capture, potential prism adaptation was also assessed. For this measure, the subject, with eyes covered, attempted to point straight ahead of his nose with his unseen index finger, both before and after prism exposure. If, after rightward prism exposure, the subject's hand felt as if it were to the right of where it had felt during the preexposure measures, he would evidence this adaptation in the postexposure trials by pointing off to the left of where he had originally perceived straight-ahead to be, since only when placed in this way would the hand feel straight ahead. Measures of adaptation were obtained for both the left (exposed) and right hand.

Procedure. The active and passive movement conditions were separated by no less than 24 h, and the order of conditions was counterbalanced across subjects. Prior to the PV measures, six

P_c and six V_c measures were taken, in that order. Throughout testing, the subject sat at a table, his head maintained in a straight-ahead position by means of a chinrest and head constraint. The P_c measures were taken in either an active or a passive manner, in accordance with the condition in which the subject was participating.

In the active condition, the subject's left arm was placed in a sling above the table top. The shutter was lowered in front of his eyes at this time and he was instructed to move his left arm laterally along the arced perimeter of the table top until the index finger contacted a vertical rod. Just as the finger stopped, he was to reach under the board with his right hand and point to its felt position. A black dot had been placed previously on the subject's right index finger to provide the experimenter with a "landmark" for comparison with a ruler affixed to the far edge of the table top. Three stopping positions and both directions of lateral arm movement were used. The stops were located straight ahead and approximately 7° on either side of straight ahead. At no time during the experiment were the subject's target and response hands allowed to touch one another.

In the passive movement condition, the subject's left arm was also in the sling. However, now he was asked to relax the entire limb as much as possible while the experimenter moved it for him. After these instructions, the experimenter lifted the subject's arm slightly and then dropped it unexpectedly, as a crude check on the subject's state of relaxation. As in the active condition, the subject was to point to the felt position of the unseen left index finger as soon as it had ceased moving.

The V_c measures occurred immediately after the P_c measures and were obtained in the same fashion for both active and passive movement conditions. They involved pointing with the unseen right hand under the table top at each of the now visible and prismatically displaced targets, which were located in the same positions as the finger-stops used for the P_c measures.

During the PV measures, the subject's left index finger was moved, actively or passively, to one of the three stopping positions. Immediately after the finger had come to rest, the shutter was raised and the subject reached under the table top with his right hand and attempted to point to the felt position of his visible, prismatically displaced left index finger. The subject was instructed to keep his eyes open and to point to where he felt the index finger to be located, regardless of where it might appear visually. Six measures were obtained, with approximately 20 sec between each trial. Actual length of prism exposure on each trial was only 2-3 sec.

To assess the possibility that the PV trials had produced adaptation, measures of felt straight-ahead were obtained. Ten preexposure measures were taken for each hand (in alternating order) immediately preceding the initial P_c measures. With vision occluded, the subject reached out beneath the table top with his hand to the left or right side of the far edge and then moved the limb laterally toward a more central position until his extended index finger was felt to be straight ahead of his nose. The postexposure measures of felt straight-ahead (five for each hand) occurred immediately after the PV measures. Finally, second sets of P_c and V_c measures were taken in order to assess the longevity of the visual capture that was expected to occur during the PV measures. To summarize, the subject's tasks and their order were: (1) felt straight-ahead position (for each arm), (2) P_c , (3) V_c , (4) PV, (5) felt straight-ahead position (for each arm), (6) P_c , and (7) V_c .

Results

The results of the experiment are presented in Table 1. As expected, the pre-post shifts in pointing straight ahead with either hand (right half of Table 1) were not significantly different from zero [$t(11) = .87$, $p > .05$, and $t(11) = .98$, $p > .05$, for left and right

Table 1
Visual Capture Ratios and Pre-Post Shifts in Felt Straight-Ahead
Position for Active and Passive Movement Conditions
(Experiment 1)

Movement Condition	Visual Capture (ratio)	Type of Measure	
		Adaptation (deg)*	
		Left Hand (exposed)	Right Hand (nonexposed)
Active	.66	-.6	+.6
Passive	.78	.0	-.1

*A negative number signifies that the pre-post shift is in the "antiadaptive" direction.

hands, respectively, in the active movement condition; $t(11) = .09$, $p > .05$, and $t(11) = .00$, $p > .05$, for left and right hands, respectively, in the passive movement condition]. In contrast, the mean capture ratios (left half of Table 1) were quite large. Both ratios were significantly different from zero [$t(11) = 26.00$, $p < .001$, and $t(11) = 33.00$, $p < .001$, for active and passive movement conditions, respectively]. A Treatment (active/passive) by Subjects analysis of variance on the capture ratios revealed a significant main effect for Treatment [$F(1,11) = 16.45$, $p < .005$], indicating that the apparent difference in visual capture in favor of the passive condition (see Table 1) is reliable.

The second set of P_c measures, taken subsequent to the postexposure measures of straight-ahead arm positioning, revealed a shift relative to the preexposure P_c measures. The pre-post shift was 2.4° for the active condition and 4.3° for the passive condition. Both shifts were statistically different from zero [$t(11) = 3.50$, $p < .01$, and $t(11) = 5.87$, $p < .001$, for active and passive conditions, respectively]. The apparent difference between the means, in favor of the passive condition, was only of borderline significance [$t(11) = 1.81$, $p < .10$].

Discussion

The major finding of Experiment 1 was that visual capture is greater for passive than for active limb movement. This is exactly the reverse of the difference typically found for prism adaptation. Thus, these results confirm the prediction that visual capture is facilitated by the degradation of limb position sense which is presumed to occur with passive movement and/or retarded by the increased precision and salience of limb position sense for the actively moved limb.

Quite unexpected was the apparent persistence of the prism-induced shift in felt limb position obtained in the second set of P_c measures, which occurred approximately 5 min after the PV measures. If this shift represents an aftereffect of visual capture, then one of the traditional distinctions between visual capture and adaptation may be in doubt. However, if the prism-induced change in felt limb position

had remained, why did it fail to lead to a pre-post shift in felt limb position as measured by pointing straight ahead? One possible explanation is that the shift in pointing accuracy from the first to the second set of P_c measures is indicative, not of a shift in felt position of the target hand, but rather of a situationally induced "cognitive" bias in reaching for this hand—a perseveration of the reaching response in which the subject had engaged during the PV trials. The tendency for this hypothesized cognitive correction to be more fully manifested with passive movement may have resulted from the fact that felt limb position was less salient or precise for this condition and, therefore, less able to signal the true position of the limb. An alternative possibility is that the pre-post shift in pointing at the stationary finger during the P_c measures did, indeed, represent prism adaptation, but that this adaptation was *suppressed* during the pointing-straight-ahead measures because the latter involved active limb movement.

Experiment 2 was designed with two purposes in mind. First, it was necessary to demonstrate that the active-passive manipulation used in Experiment 1 was sufficient to produce the traditional difference in prism adaptation. Second, it was important to prove that the straight-ahead reaching response was sensitive to prism-adaptive shifts in felt limb position.

EXPERIMENT 2

Method

Subjects. The same 12 subjects used in Experiment 1 participated in this experiment, which occurred no more than 2 weeks later. Again, the subject served as his own control in active and passive limb movement conditions.

Procedure. The subject sat at the table used in Experiment 1. At the onset, he alternated between placing first his unseen left hand and then his unseen right hand such that, in each case, the hand was felt to be straight ahead of his nose for a total of 10 responses with each hand. Next, six P_c measures were obtained, followed by six V_c measures. The P_c measures were taken in either the active or passive fashion described for Experiment 1, depending on the subject's limb-movement condition. Then a series of four 2-min prism adaptation periods were instituted, each followed by five measures of felt straight-ahead position with each hand. During the prism-exposure periods in the active movement condition, the subject's left arm was held by the sling as he viewed it through the prism and moved it from a central starting position to one or the other of two stops, located 20° apart and positioned so as to appear symmetrical with respect to apparent straight-ahead when seen through the prism. The stop to which the subject was to move the index finger on a given trial was indicated by the experimenter every 2.5 sec, in a random order, which was different for each of the 2-min exposure periods. In the passive movement condition, the subject's left arm was in the sling and he was instructed to relax it as much as possible. The experimenter moved the hand from stop to stop every 2.5 sec. The last set of five felt straight-ahead position measures for each limb was followed by six P_c and six V_c measures. Next, the prism goggles were removed and the subject actively swung his visible left hand back and forth between two stops, located 10° to the left and right

of straight-ahead. This "unlearning" period lasted 3 min. Its purpose was to eliminate the subject's adaptation prior to a final set of five straight-ahead arm positioning responses with each hand, with eyes closed.

Results

The index of adaptation was the difference between (1) the average of the combined preexposure and post-"unlearning period" straight-ahead arm positioning responses and (2) the average of the five responses that occurred immediately after a given 2-min prism exposure period.³

No adaptive pre-post shift in felt straight-ahead position was found for the right (nonexposed) hand in either of the arm-movement conditions for any of the four adaptation tests. The results for the left (exposed) hand are depicted in Figure 1. The baseline measures for the two conditions were not significantly different from each other and were adjusted to zero for the purposes of the figure. The remaining points each represent the difference between the baseline measure and the measure on a given adaptation test. It is clear that only the active movement condition led to adaptation and that this adaptation increased as a negatively accelerated function of exposure time. According to *t* tests, the points at Exposure Tests 2, 3, and 4, but not 1, were significantly greater than zero [$t(11) = 1.82$, $p > .05$, $t(11) = 4.88$, $p < .001$, $t(11) = 5.62$, $p < .001$, and $t(11) = 4.87$, $p < .001$, for Tests 1, 2, 3, and 4, respectively]. The apparent "antiadaptive" shifts for the passive movement condition on Tests 1, 2, and 3 and the slight adaptive shift on Test 4 were not significant. A Treatment by Tests by Subjects analysis of variance revealed significant effects for treatment (active/passive) and Tests (1, 2, 3, 4) [$F(1,11) = 9.29$, $p < .025$, and $F(3,33) = 5.09$, $p < .01$, respectively]. The interaction was not significant [$F(3,33) < 1.0$].

Figure 1. Adaptation curves for the left (prism-exposed) hand for active and passive movement conditions over four 2-min prism-exposure periods (Experiment 2).

An examination of the P_c and V_c measures revealed a significant pre-post shift for the former [$t(11) = 6.00$, $p < .001$, and $t(11) = 6.16$, $p < .001$, for active and passive conditions, respectively] and for the latter [$t(11) = 2.97$, $p < .02$, for the active but not for the passive condition, $t(11) = 1.07$, $p > .05$]. The shift for V_c was in the "antiadaptive" direction. Although a shift in the P_c response for the exposed hand was expected for the active movement condition, it is not clear why the passive condition, which failed to produce a shift in the felt straight-ahead position, nevertheless led to a shift in the felt position of the hand when pointed to with the other hand. Again, however, this anomaly may have resulted from the fact that the finger was stationary during the P_c measures but actively moving for the straight-ahead limb positioning responses. The mean shifts (4.3° and 3.9° for the active and passive conditions, respectively) were not statistically different [$t(11) = .55$, $p > .05$].

Discussion

The shift in felt position of the prism-exposed limb found in the active movement condition of the present experiment clearly qualified as adaptation by the criteria stated previously. It reached asymptote only gradually, it persisted subsequent to the exposure period, and it occurred only in the active movement condition. Thus, Experiment 2 succeeded in replicating the traditional active-passive difference in adaptation and simultaneously proved that the straight-ahead limb-positioning task was capable of detecting prism adaptation.

GENERAL DISCUSSION

As predicted, active limb movement was found to retard visual capture and facilitate adaptation, whereas passive movement led to the opposite effects. The basis of this prediction was the assumption that the active/passive manipulation serves to alter the precision and/or salience of felt limb position.

In an attempt to test the modality precision hypothesis as it applies to the present results, the standard deviation of all the P_c measures for the active conditions of both experiments was computed for each subject, and, likewise, the standard deviation of all the V_c measures. The same was done for the passive conditions of both experiments. Then the ratio of each subject's P_c standard deviation to his V_c standard deviation was taken. The group means for these combined modality precision estimates are presented in Table 2. In line with the present argument, the mean standard deviation for the proprioception measures (SD_{prop}) proved to be significantly smaller for the active than for the passive movement condition [$t(11) = 3.64$, $p < .01$].

Table 2
Proprioceptive and Visual Precision (Standard Deviations in Degrees) Based on the Combined Control Measures of Experiments 1 and 2

Movement Condition	Precision Measure		
	SD _{Prop}	SD _{Vis}	SD _{Prop} /SD _{Vis}
Active	1.94	1.63	1.80*
Passive	2.46	1.43	2.63*

*This ratio was calculated by computing the SD_{Prop}/SD_{Vis} for each S separately and then taking the mean of these ratios. It is not the ratio of the SD_{Prop} to the SD_{Vis} from the preceding two columns.

There was no difference for the V_c measures [$t(11) = 2.05$, $p > .05$], and none was expected, because these were taken in exactly the same fashion in the two limb-movement conditions of both experiments. The most important measure is the ratio of P_c to V_c standard deviations. This proportion was significantly greater for the passive movement condition [$t(11) = 3.49$, $p < .01$]. Thus, the latter condition, which facilitated visual capture and inhibited adaptation, revealed the greater difference in precision between the P_c and V_c measures. This result is congruent with the notion that facilitation of visual capture accompanies a relatively large intersensory difference in precision, whereas adaptation is reduced in the same situation. Further support for the role of modality precision was provided by the correlations between the SD_{Prop}/SD_{Vis} ratio and the visual capture ratio. The Pearson product-moment correlations were .69 ($p < .01$) for the active movement condition and (with one "outlier" removed) .73 ($p < .005$) for the passive movement condition. These positive correlations signify that the larger the ratio of proprioceptive to visual variability, the greater the visual capture. An argument might reasonably be made that the ratio of proprioceptive to visual precision is highly correlated with the relative amount of *attention* elicited by or directed toward the two modalities and that this is actually the crucial factor operating to produce both the difference between the conditions and the within-group correlations. Unfortunately, this possibility cannot be assessed in the present experiment.

The correlations between the shift in felt straight-ahead limb position from Experiment 2 and the combined-experiments proprioception-vision precision ratio did not prove statistically significant [$r = .33$, $p > .05$, and $r = .41$, $p > .05$, for active and passive movement conditions, respectively]. The failure to obtain a significant negative correlation between precision ratio and adaptation suggests, contrary to the present formulation, that the relative precision of vision and proprioception are not important for adaptation. Alternatively, the lack of a relationship between these two measures might have resulted

from the difference in relative activity of the limb for the P_c and straight-ahead positioning responses, as suggested previously. If the measure of adaptation had involved a passively moved or stationary limb, it is possible that the predicted correlation between adaptation and the relative precision of proprioception and vision would have been obtained.

CONCLUSIONS

The results of the present investigation lead to the conclusion that visual capture and visuomotor prism adaptation are based on dissimilar processes, since the active/passive manipulation had opposite effects on the two phenomena. Although the experiments were not designed to investigate the nature of the processes, it was speculated that the active/passive manipulation served to create differences in the degree of registered visual-proprioceptive discordance and that visual capture is facilitated by degraded proprioceptive input, whereas adaptation requires for its induction a relatively strong discordance. Even if this is true, it is still unclear if the presumed increase in discordance (for the active limb condition) is the result of increased precision, increased attention, or some other factor such as the presence of "efferent instructions" to the limb. In short, the comparison between active and passive limb movement is an intrinsically confounded one, and further studies are required to determine the relative importance of the various potential attributes of active movement for visual capture and adaptation.

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NOTES

1. In the present paper "proprioception" and "felt limb position" are used interchangeably. Ideally, the term "proprioception," which refers to neural inflow (afference) signaling the relation of one body part to the remainder of the body, should be limited to situations in which the limb is stationary or passively moved. With active movement, it is likely that both inflow and outflow (efference) underlie the felt relation of body parts, and, therefore, the more neutral term "felt limb position sense," or a derivative, should be used.

2. Although the term "visual capture" connotes *complete* dominance of vision over proprioception, most investigations have actually found the extent of the intersensory bias to be less than 100%.

3. The reason for combining the preexposure and post-"unlearning" responses in calculating the "baseline" measure was to take into consideration any "drift" in arm positioning that might occur over the course of the experimental session for reasons unrelated to adaptation. It was assumed that any adaptation that might occur would be eliminated by the "unlearning" period. However, if some adaptation remained, it would only serve to reduce the pre-post shift obtained.

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