Learning in image-guided reaching changes the representation-to-action mapping

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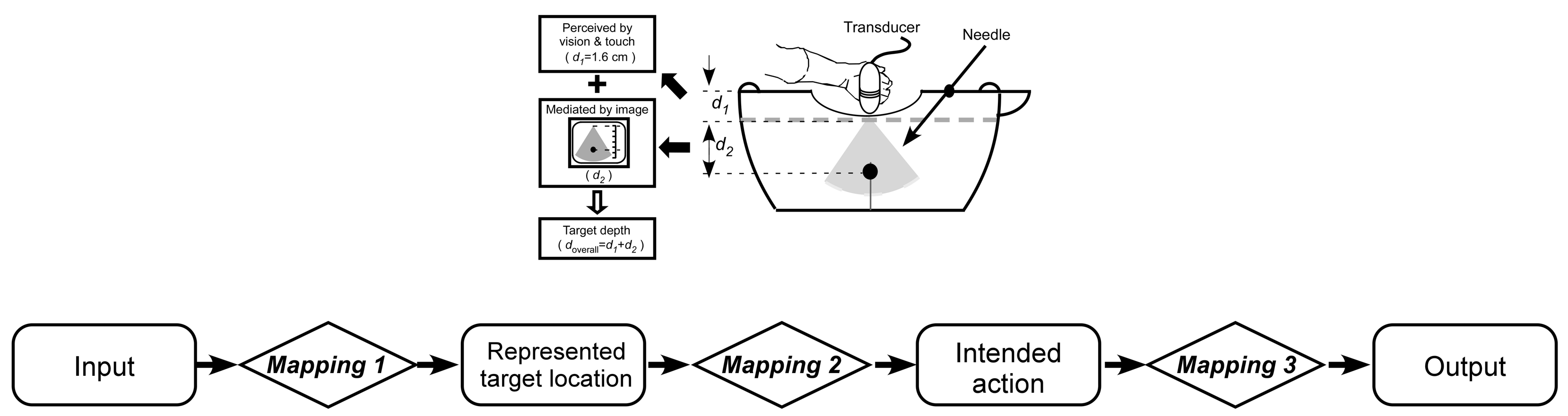
Introduction.

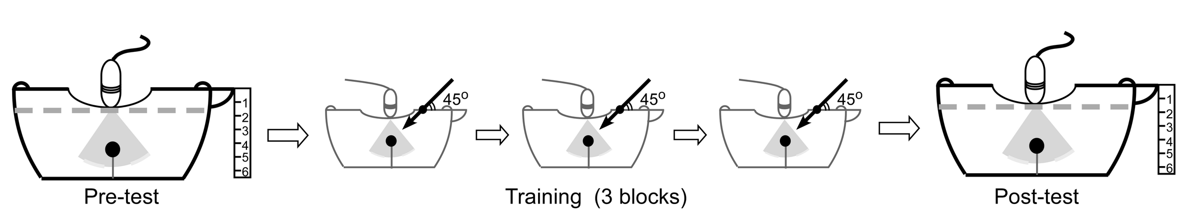
Actions are directed not only by perceptual channels, but by cognitive mediational processes that generate spatial descriptions, as in encoding the location of a hidden target imaged with ultrasound. Reaching to such a target with a needle shows systematic error, but as with perceptually guided action, performance can be corrected by training with feedback (Klatzky, et al., in press). Where and how does corrective adaptation occur? We distinguish among three mappings shown below, any of which could be a locus for adaptation during training.



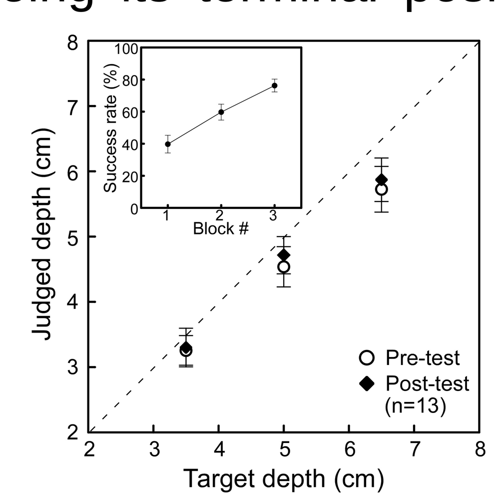
Exp 1: Mapping 1: From input to representation

Exp 1a: If training could change the mapping from the input image to a spatial representation of target location, we would expect subjects' judgments of target depths to become more accurate.

Stimuli & Task: Subjects reported the depth of ultrasound-imaged targets (3.5, 5.0, 6.5 cm) with a visual matching paradigm before and after training trials. During the training, they repeatedly guided a needle toward a target (5.0 cm) and received feedback by seeing its terminal position in the ultrasound image.



(a) Design of Exp 1a

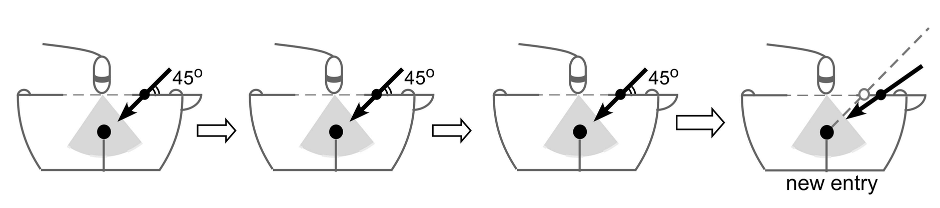


(b) Judged target depths before and after training
(The inset figure shows the mean success-rate of insertions across training blocks)

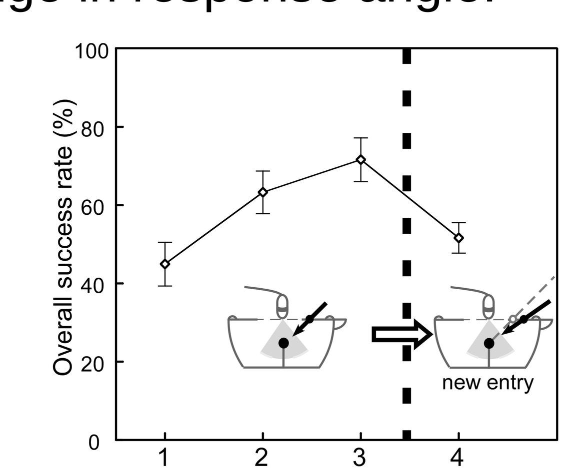
Results: Although reaching accuracy improved with training, there was no corresponding change in visual matching. Judged target depth was consistently under-estimated.

Exp 1b: If training led to changes in target localization, it should transfer to a new posture directed at the same location. Insertion toward the same target from a new response point would show no error after adaptation.

Stimuli & Task: After training as in Exp 1a, subjects immediately proceeded to aim toward the same target but from a new, unpracticed response point, requiring a change in response angle.



(a) Design of Exp 1b



(b) Success-rate of insertions across training and transfer blocks.

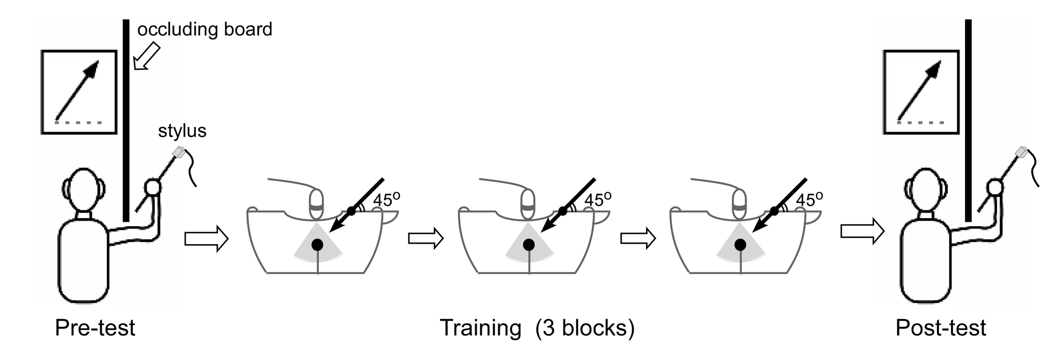
Results: Subjects' performance dropped dramatically after transfer, disconfirming the hypothesis.

Combining these results, we conclude that learning occurred not at the mapping from input to representation but at subsequent mappings from the representation to the motor response.

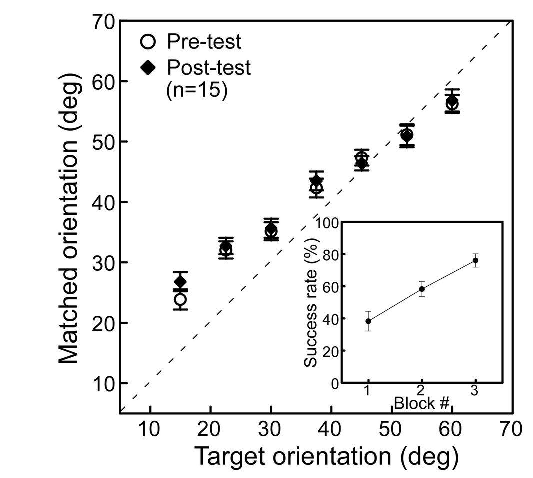
Exp 2: Mapping 3: From intended action to motor output

If learning compensated for encoding errors by modifying the mapping from the intended response angle to the action, motor responses after training should be altered.

Stimuli & Task: Before and after a series of training trials, subjects were tested in a haptic-matching task, which required them to hold and rotate a stylus with their unseen hand in order to make it parallel to a visual orientation (ranging from 15º to 60º with a step of 7.5º).



(a) Design of the experiment



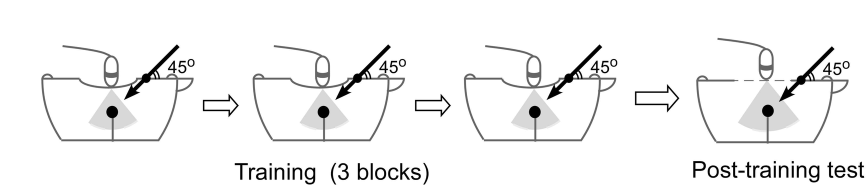
(b) Matched orientations before and after training
(The inset figure shows the mean success-rate of insertions across training blocks)

Results: No change was found in subjects' motor responses, disconfirming the hypothesis.

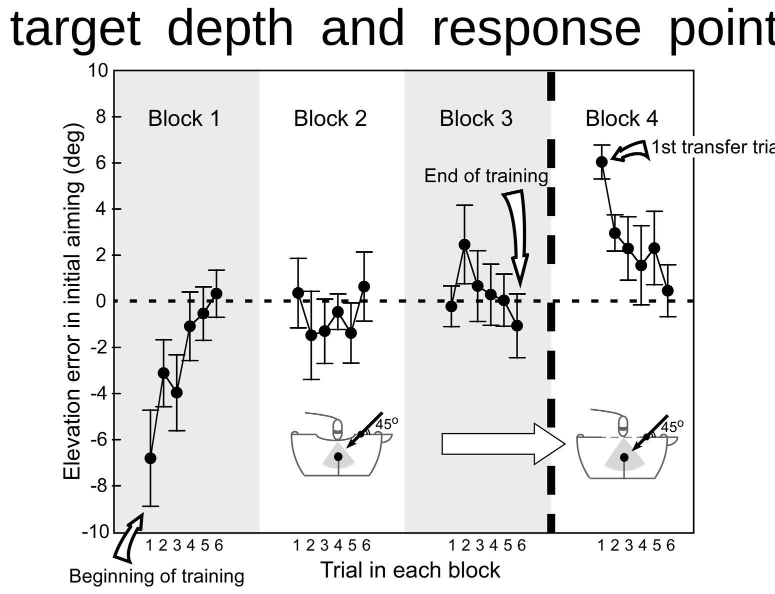
Exp 3: Mapping 2: From representation to intended action

In studies so far, subjects under-represented depth before training but learned to compensate by aiming deeper. If training changed the mapping from representation to intended action, then subjects should over-shoot a target whose depth is represented accurately. We induced a more accurate depth judgment of the same target by eliminating the indentation in the tank lid. Assuming full transfer of adaptation, error should be predictable from the amount of training-induced adaptation and the error in representing the current target depth.

Stimuli & Task: Subjects were first trained with a tank with a 1.6-cm indentation and then transferred to another tank with no indentation. The target depth and response points were identical across different tanks.



(a) Design of the experiment



(b) Elevation error in the initial aiming of the needle.

Results: (1) As expected, overshooting errors were found in the first trial after transfer.

(2) The amount of overshooting (6.0º±0.7º) was close to the prediction based on a combination of the training-induced adaptation (6.8º) and the error from estimation of target depth (-2.0º).

Conclusion:

(1) No training-induced changes were found in Mapping 1 & 3.

(2) Training modified Mapping 2, which associates the representation of target location with the intended response angle.

Reference:

Klatzky, Wu, Shelton & Stetten (in press). Effectiveness of augmented-reality visualization vs. cognitive mediation for learning actions in near space. ACM Transactions on Applied Perception.