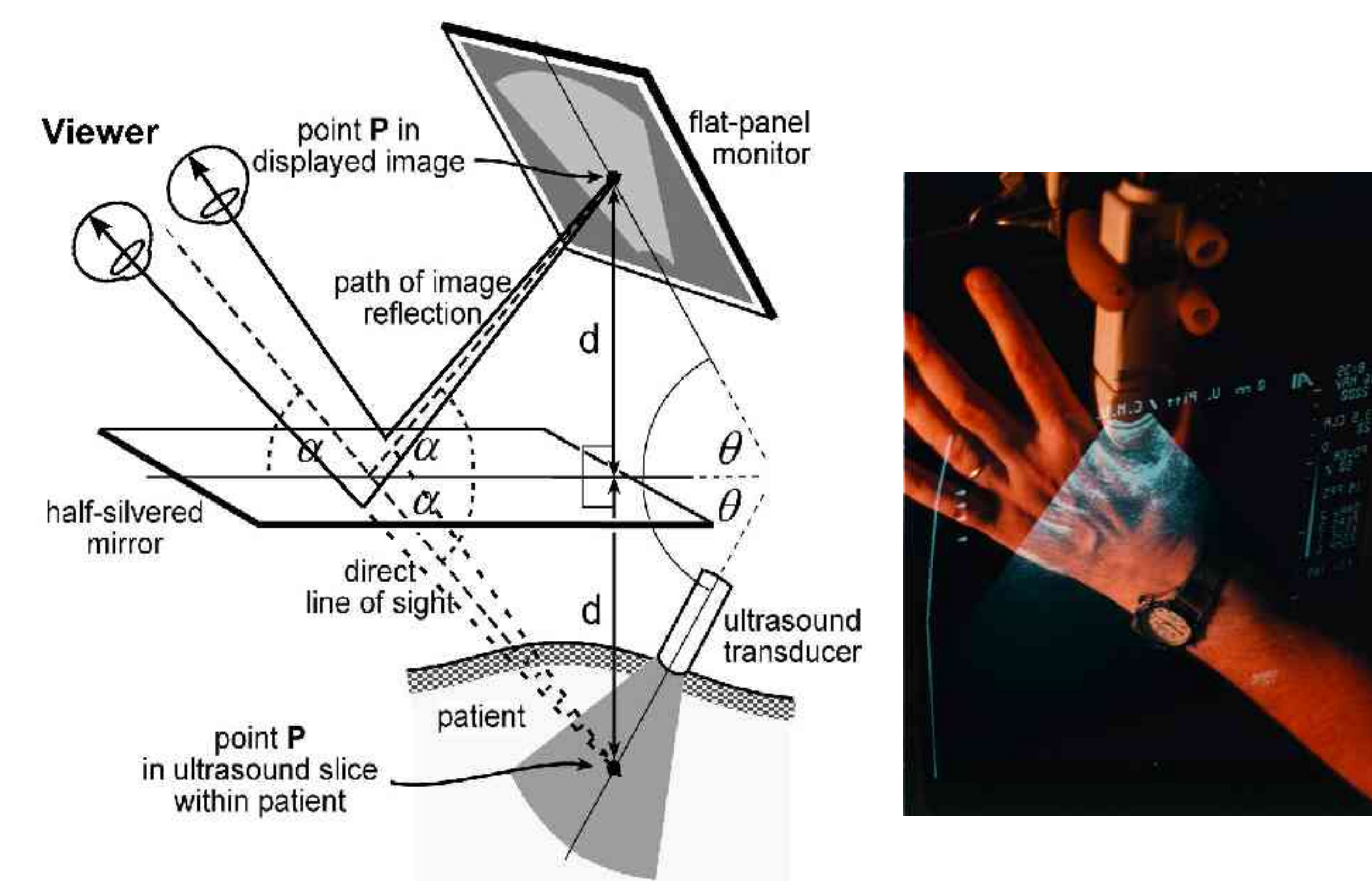
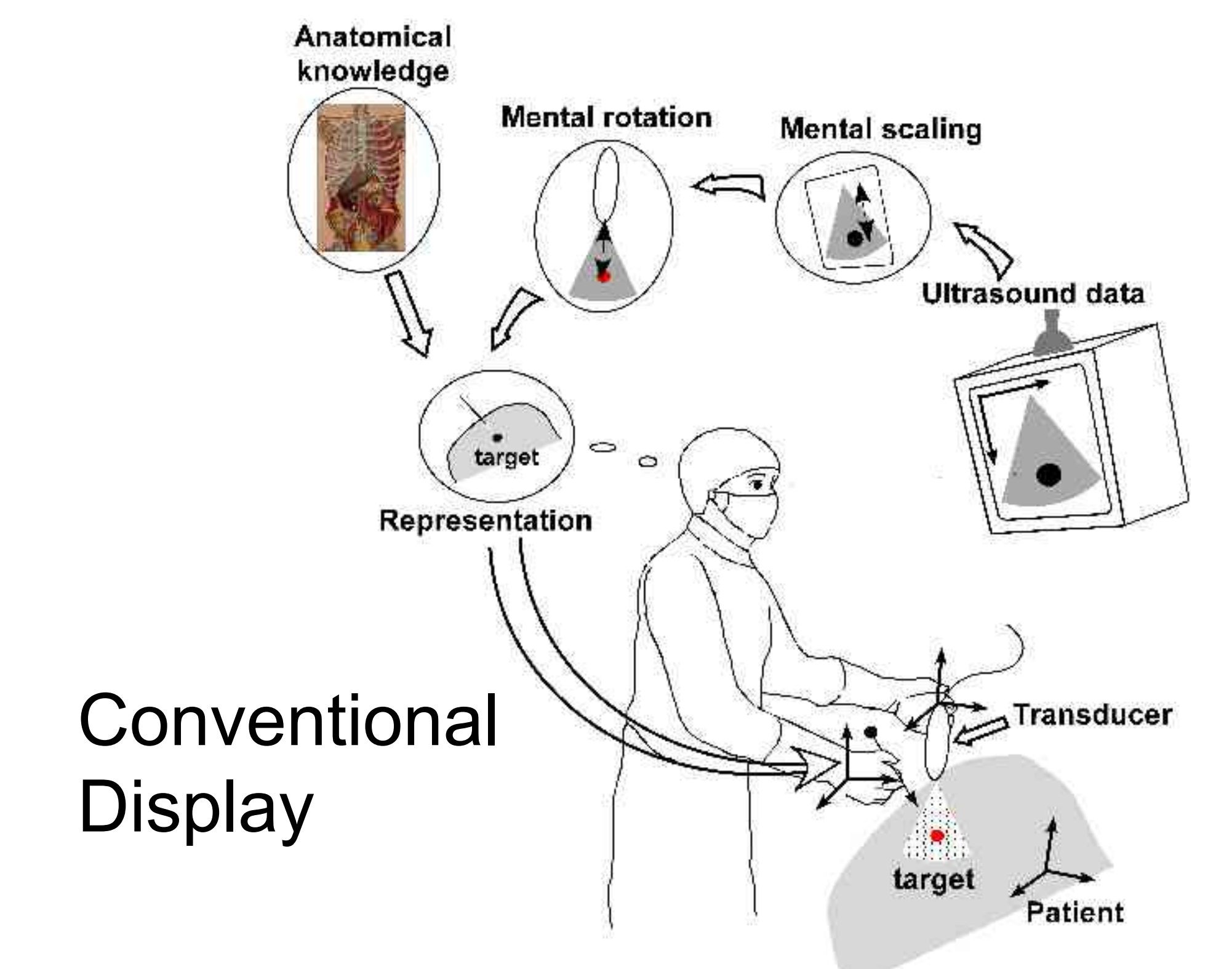


Introduction. Spatially directed actions controlled by different visualizations present different processing demands and ultimately produce different performance. We investigated this in very near space in the applied context of ultrasound-guided surgical manipulation.

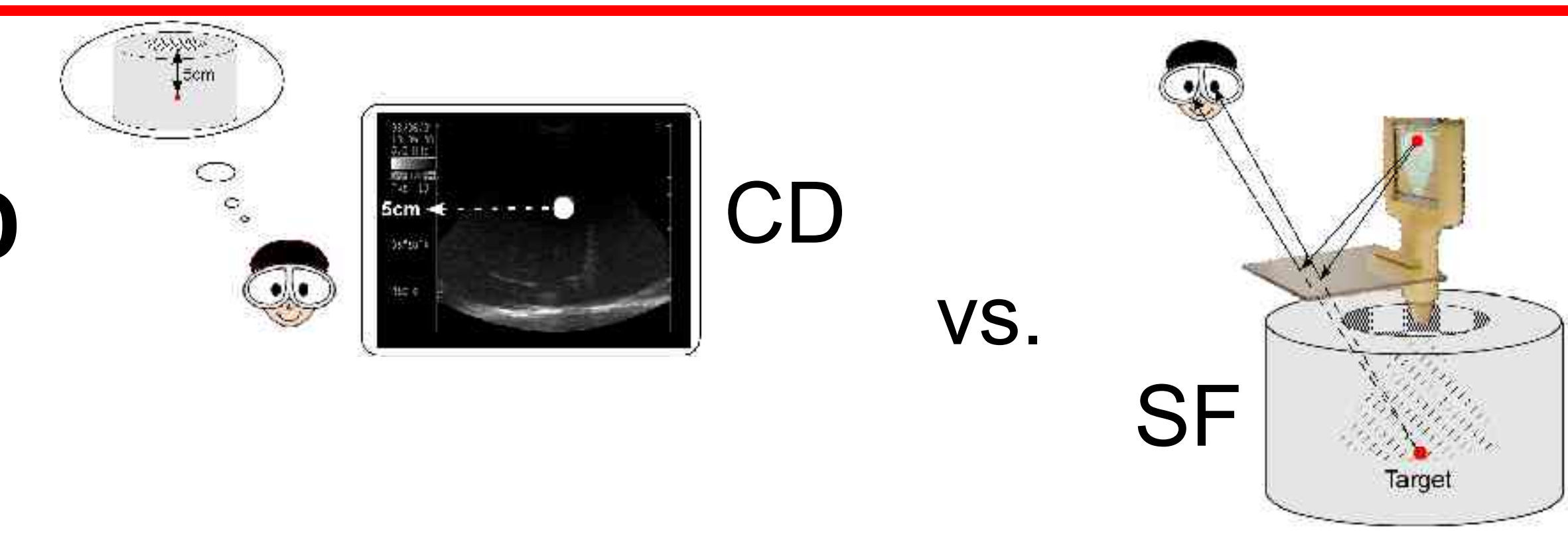
The **Conventional display (CD)** (right) shows images on a screen on which depth is marked by a metric. Image-based actions, such as ultrasound-guided interventions, therefore require building a mental model of target location through cognitive processes, including size rescaling, coordinate transformation, and top-down interpretation. High error rates have been observed for CD-guided surgical interventions.



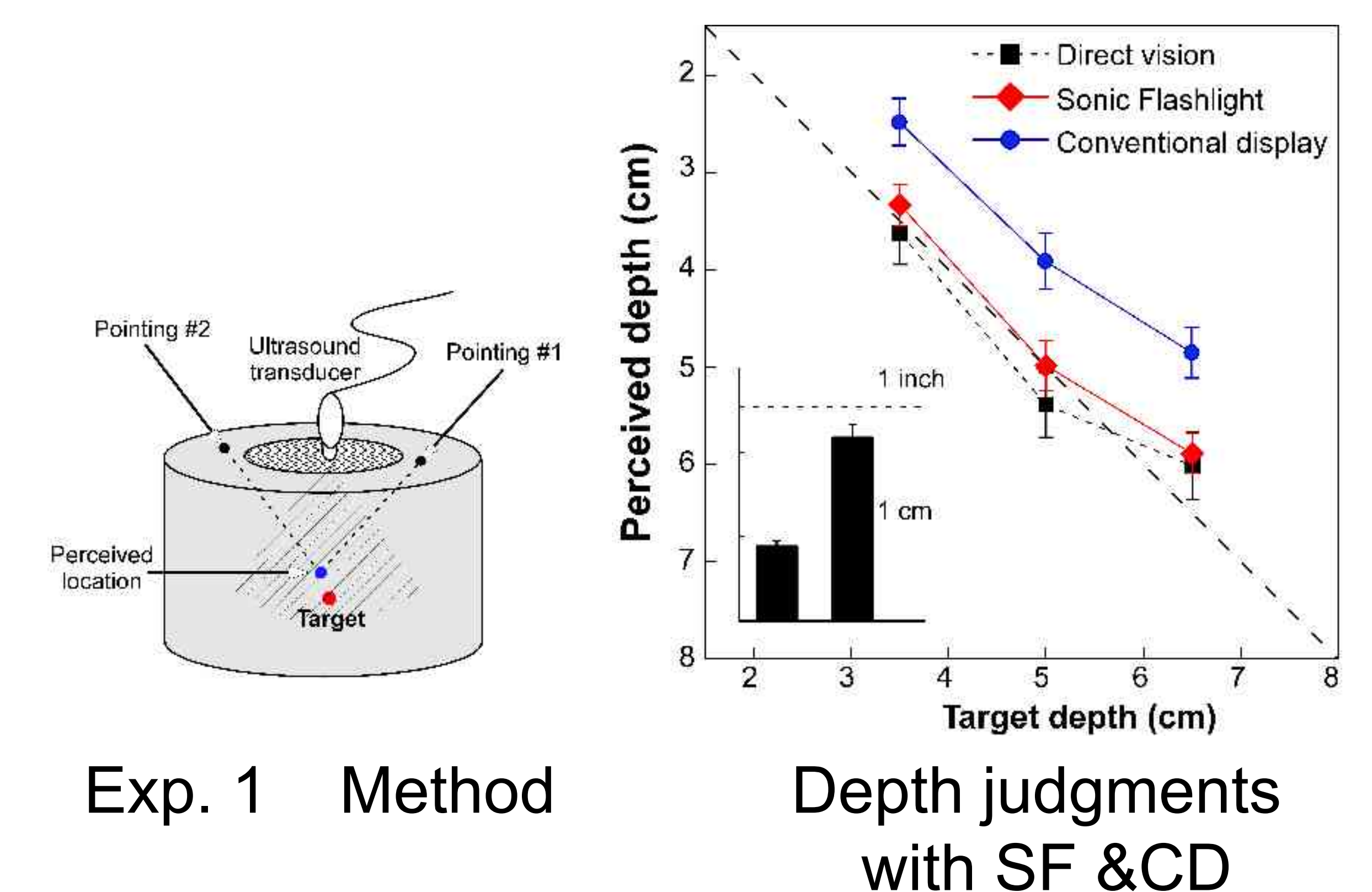
Optics and demonstration of the SF

The **Sonic Flashlight (SF)** (left), an augmented-reality visualization device developed by Stetten, uses optics to display the ultrasound slice superimposed on the body at the precise 3-D location of the imaged data. Viewed through the half-silvered mirror, the display provides binocular depth cues and requires no cognitive transformations. Are perceptual cues superior for guiding action?

We compared the SF to CD in three experiments.

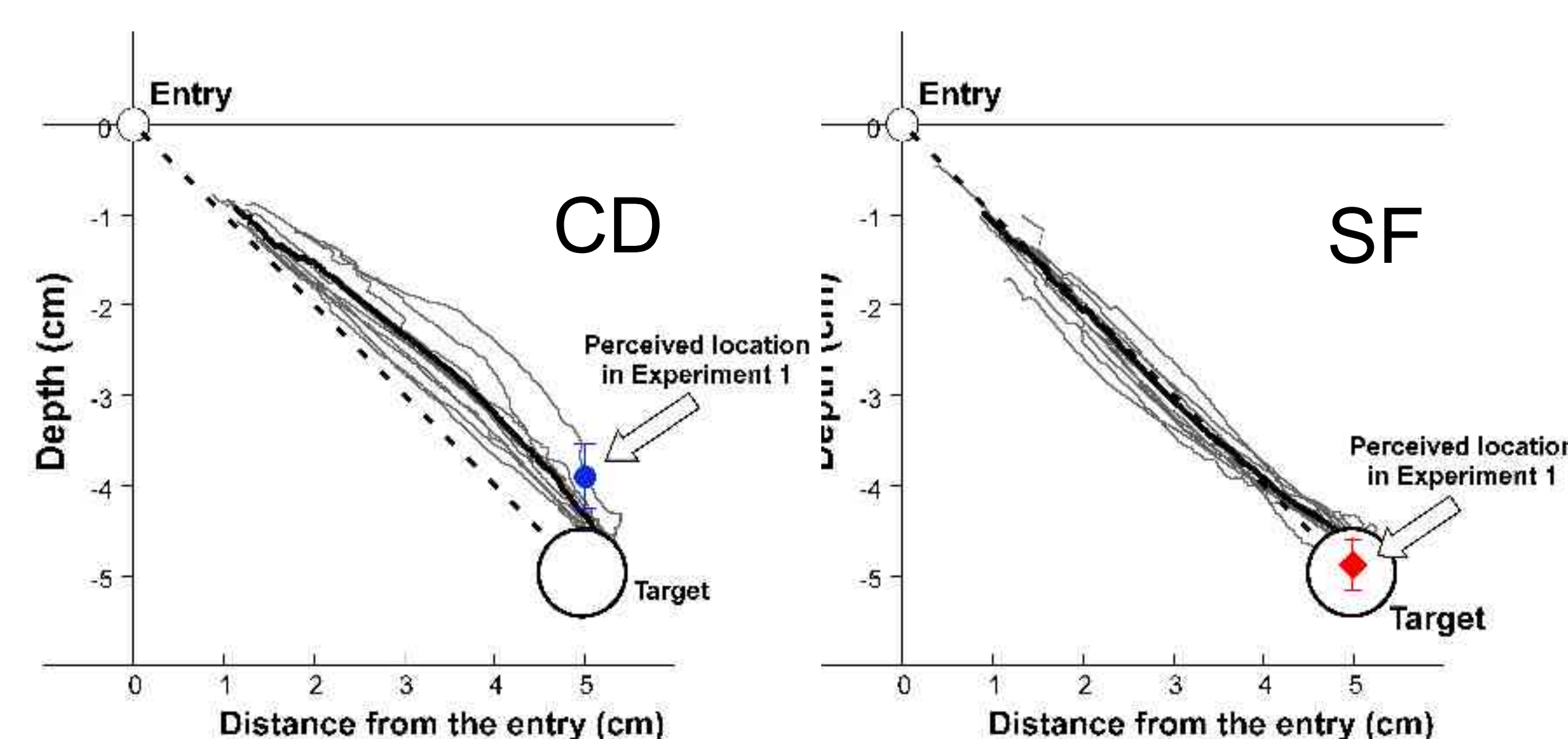


Experiment 1: Target localization. Using the SF or CD, subjects pointed to a target ball in an opaque fluid from 3 response positions while tracked by an instrumented stylus. From the pointing intersections we computed the represented target location. **Results:** The SF was equivalent to direct sight of the target, whereas CD led to systematic under-estimation of depth, despite subjects' understanding of the metric scale.



Exp. 1 Method

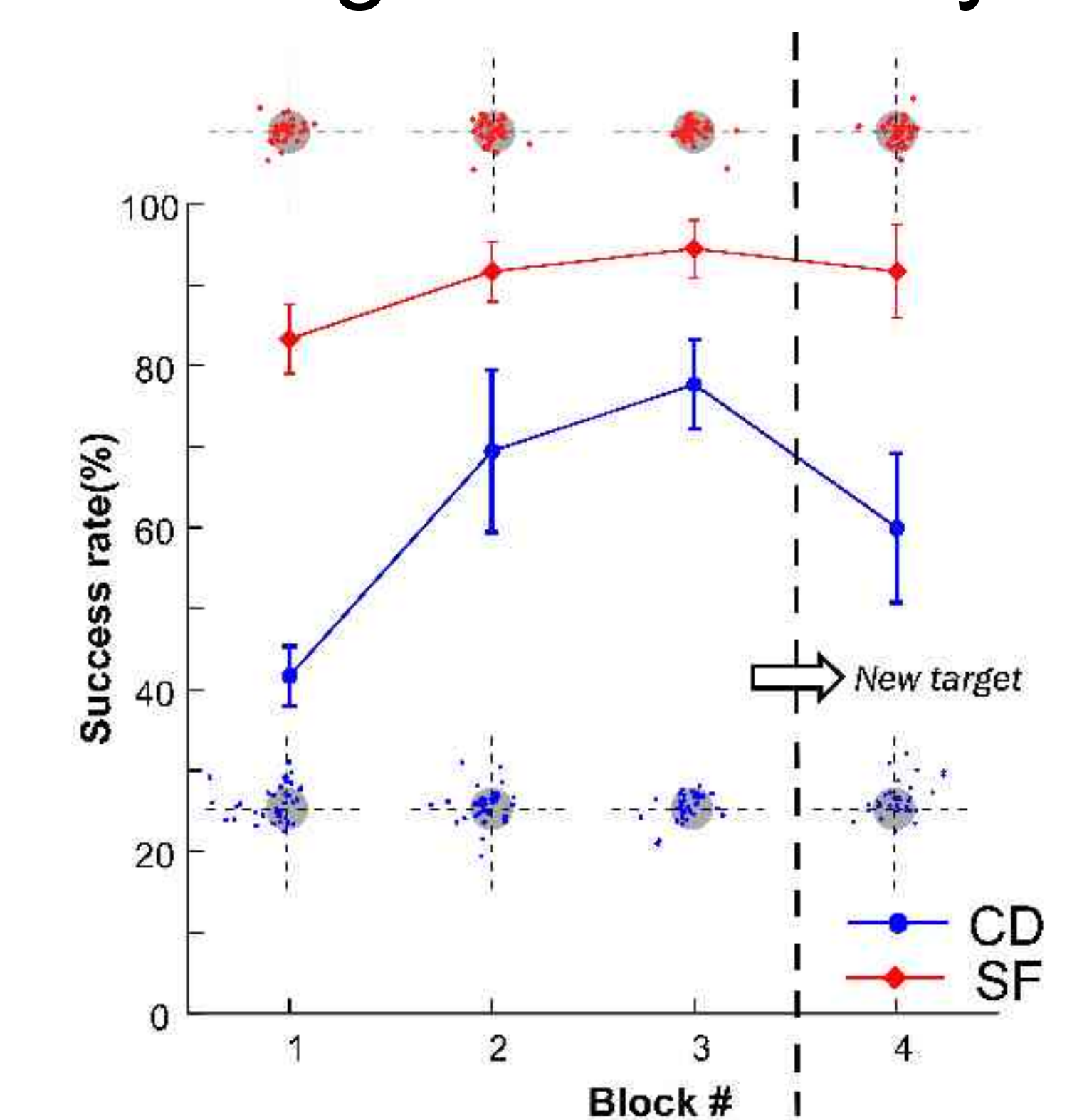
Depth judgments with SF & CD



Exp. 2 Average trajectories

Experiment 2: Reaching to target. Using the SF or CD, subjects guided a needle to a target ball. **Results:** With the SF, reaching was accurate, whereas CD led to systematic error that was consistent with the previous under-estimation of depth. After aiming too high with CD, subjects descended toward the target when they saw the needle in the image plane. This would not be feasible in surgical practice.

Experiment 3: Learning. Using the SF or CD, subjects repeatedly reached for the same target, then transferred to another at a different depth. **Results:** The subjects showed significant learning in the CD-guided insertions, but their performance dropped considerably when transferring to a new target. In contrast, the SF led to high accuracy even before extensive practice, and little change was found in the transfer trial. Positional consistency showed the same pattern.



Exp. 3 Success rate & response distribution

Conclusion. The perceptually based display (SF) guided action with greater precision, faster learning, and broader transfer. Further experimental work is investigating the basis for systematic errors with cognitively guided action (CD). Our work is also being directly applied to clinical trials.