Characterizing reach strategies in ambiguous tasks

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How does the brain develop a control strategy for tasks like reaching to a line or grasping a cylinder that do not have unique solutions? One possibility is that particular points on the line or cylinder are selected as targets by minimizing generic motor costs (e.g. the proximity of the target the initial hand configuration or the control cost of acquisition). These selected targets could then be used to drive a feedback controller that minimizes distance to the target. However, it is also possible that the brain maintains a representation of solution ambiguity during control, to allow for control strategies that adapt goals to provide robustness against noise, sensory error, and changes in the environment. These two strategies behave differently under a perturbing force field mid-reach: the first corrects the perturbations, while the second adapts by contacting the new closest viable point. The goal of this study was to test these possibilities psychophysically, and to develop computational methods for characterizing control strategies to ambiguous targets. Participants used a PhanTom to virtually touch graphically rendered lines that appear at various orientations on a virtual surface. During some trials, a force (oriented in various directions with respect to the line) perturbs the movement. If participants maintain solution ambiguity, they should “go with the flow”, taking advantage of the perturbing force to the extent that it doesn’t affect task success. Conversely, if subjects use target selection, then we should see attempted correction of the perturbing forces in all conditions. Qualitatively, we found that reaches "go with the flow", which suggests that the brain visually encodes and uses the set of viable contact points to construct control policies. Moreover, when the line lengths were made shorter, the amount of corrective force increases with decreases in line length, suggesting that policies are explicitly based on cost functions that encode task success rather than target acquisition. To quantify action policies and estimate the cost functions effectively used by participants, we use non-parametric Bayesian regression to learn state-action visit distributions conditioned on initial state and the reward for each task. Using the assumption that these state-action visit distributions are optimal for some cost function defined on state-action pairs, we show how reach behavior can be interpreted in terms of equivalent cost functions.

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