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Review

Prism adaptation and unilateral neglect: Review and analysis

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Abstract

Theory and data from normal prism adaptation are applied toward understanding the ameliorating effects of prism adaptation for left unilateral neglect patients. Neglect is proposed to be, at least in part, a dysfunction in selection of the region of space appropriate for the task at hand. Normally, a task-work space is strategically sized and positioned (calibrated) around the task-relevant objects. Patients show deficits in both strategic abilities: the task-work space is pathologically reduced in size and patients cannot strategically shift its position. Prism adaptation (spatial realignment) ameliorates dysfunctional positioning, but not sizing of the task-work space. Realignment shifts the egocentric coordinates of a sensory–motor reference frame, thereby bringing at least part of the neglected hemispace into the dysfunctional task-work space: prism adaptation substitutes for dysfunctional positioning, but not sizing of a task-work space. However, such amelioration of dysfunctional positioning may enable relearning of strategic processes (calibration), perhaps, even partially restoring the ability to appropriately size the task-space. Investigation of therapeutic prism adaptation requires methods that permit identification of both the calibration dysfunction and ameliorating realignment.

Keywords: Realignment; Recalibration; Aftereffects; Muscle-potentiation; Motor control

Contents

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1. Introduction

A short period of adaptive pointing toward targets optically displaced rightward by prisms ameliorates many clinical symptoms of right-hemisphere stroke patients who neglect their left-hemispace (Rossetti et al., 1998). The therapeutic effect of prism adaptation on unilateral neglect is becoming an increasingly important research area in neuropathology (for reviews, see Mattingley, 2002; Rode, Pisella, Rossetti, Farnè, & Boisson, 2003; Rossetti & Rode, 2002). In the present paper, we seek to further this research effort by interpreting the therapeutic effect in terms of the most current data and theory of normal prism adaptation (Redding & Wallace, 1993, 1997a, 2002, 2003a). We believe it incumbent upon researchers who apply prism adaptation for therapeutic purposes that they be conversant with normal prism-adaptation theory and method (see also, Redding, Rossetti, & Wallace, 2005).

In the 100 years since its discovery, prism adaptation has been interpreted first in terms of perceptual theory (Held & Hein, 1958; Kohler, 1951/1964; von Helmholtz, 1909/1962) and later in terms of learning theory (Bedford, 1989; Welch, 1978). These early explanations of prism adaptation have now been incorporated into a motor control interpretation (Redding & Wallace, 1993, 1997a). Understanding normal prism adaptation necessarily requires some understanding of motor control; prism adaptation is a particular example of adaptive perceptual–motor control. Therefore, we must begin with a review of the basic concepts from motor control relevant to prism adaptation.

With necessary motor control concepts in hand, we review the current state of data and theory in prism adaptation and draw out the methodological implications for application of the procedure. We then survey the research showing therapeutic effects of prism adaptation on unilateral neglect. Next, we apply current prism adaptation theory to explain therapeutic effects. Finally, we conclude with recommendations that may increase our understanding of prism-adaptation therapeutic effect. Note carefully that our purpose is not to explain all of the various facets of unilateral neglect. Rather, our modest goal is to understand how prism adaptation ameliorates at least some kinds of neglect.

2. Basic concepts of motor control

This review of perceptual–motor control is selective. It is neither meant to be exhaustive of this large area of data and theory nor even to necessarily represent all of the most central problems that concern motor-control theorists. We present only the concepts relevant to prism adaptation (see also Redding & Wallace, 1997a). For more detailed treatments, we refer the interested reader to books by Rosenbaum (1991) and Schmidt (1999) and reviews by Kawato (1996a,b).

When one undertakes a routine, perceptual–motor, goal-directed task a number of strategic processes are activated at different levels of a hierarchical representation of the goal-behavior. For example, the intention to grasp a coffee cup retrieves a previously learned coordinative structure (synergy) linking sensory–motor systems from eye to hand (a different coordination of sensory–motor systems would be retrieved, for example, by the intention to walk to the restroom). Retrieval of an eye–hand coordinative linkage constitutes a super-ordinate or generalized movement plan (schemata), a plan to use the hand on some seen object, a plan for control (guidance) of the limb by visual input. If the task were to look at one's wristwatch, for example, the reverse direction of guidance of the eye by limb proprioception and a different generalized movement plan would be retrieved. The generalized movement plan includes input–output details at subordinate levels to achieve a task-specific movement plan.

On the input (visual–motor) side a *regional work space* is identified to include the goal object among surrounding objects that might constitute obstacles to movement: inclusion of the entirety of, for example, visual space and its contents would produce an unduly heavy computational load and consequential performance errors. A regional task-work space might be thought of as the focus of spatial attention, but whenever possible we adopt a description in terms of task parameters, with minimal invocation of endogenous processes. We call such strategic positioning of the task-work space and its contents within a larger reference frame "calibration", the process of setting the spatial parameters for a specific task. Information from the visual task-work space is used to select a more specific movement plan, ultimately specifying the movement path required to negotiate obstacles to reach the goal object (coffee cup). Of course, the specific movement plan includes specification of a grasping (rather than, for example, a touching) hand posture. This visually prescribed movement plan is sent as a feedforward movement command structure to the limb.

A feedforward movement plan involves a predicted movement sequence such that deviations can be anticipated and quickly corrected before they can occur or at least before they can become large. For example, inertial differences be-