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Review

Applications of prism adaptation: a tutorial in theory and method

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Abstract

Data and theory from prism adaptation are reviewed for the purpose of identifying control methods in applications of the procedure. Prism exposure evokes three kinds of adaptive or compensatory processes: postural adjustments (visual capture and muscle potentiation), strategic control (including recalibration of target position), and spatial realignment of various sensory-motor reference frames. Muscle potentiation, recalibration, and realignment can all produce prism exposure aftereffects and can all contribute to adaptive performance during prism exposure. Control over these adaptive responses can be achieved by manipulating the locus of asymmetric exercise during exposure (muscle potentiation), the similarity between exposure and post-exposure tasks (calibration), and the timing of visual feedback availability during exposure (realignment).

Keywords: Prism adaptation; Realignment; Recalibration; Visual capture; Unilateral neglect; Sensory-motor transfer

Contents

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The recent resurgence of interest in application of prism adaptation methodology promises to increase our understanding of both normal perceptual-motor control (e.g. Fernández-Ruiz et al., 2000; Kitazawa et al., 1995; Kitazawa et al., 1997; Martin et al., 1996a; Martin et al., 2002; Roller et al., 2001) and neuropathology (e.g. Berberovic et al., 2004; Farnè et al., 2002; Ferber et al., 2003; Frassinetti et al., 2002; Maravita et al., 2003; Pisella et al., 2002; Rode et al., 1998/1999; Rossetti et al., 1998; Tilikete et al., 2001). Adaptation to prismatic displacement is particularly suited for application because its incremental nature permits examination over relatively short time periods, in contrast to prismatic distortions like left-right or up-down reversal of the visual field that involve discrete, all-or-none adaptive states and require extended exposure for adaptation to occur (e.g. Sekiyama et al., 2000; Stratton, 1897a; Stratton, 1897b; Taylor, 1962). However, recent application has not always taken into consideration the long history (e.g. Held and Hein, 1958; Helmholtz, 1909; Kohler, 1951) and complexity of prism adaptation (Redding and Wallace, 1993, 1997a, 2002, 2003a). Consequently, the promise of application has not been fully realized. Here, we sketch the current state of knowledge in prism adaptation and the methodology needed for maximal benefit from its application. We will show that prism adaptation is not a simple process and, while the procedure can be used for many different applications, certain minimal methodological standards should be met before the procedure is developed for a specific application.

We begin by listing the primary empirical characteristics of prism adaptation. Then we impose order on the empirical facts by identifying the various processes of prism adaptation that must be methodologically segregated. Next, we sketch the perceptual-motor organization supporting the various adaptive processes, especially how they are interrelated. Then we critique some examples of application of the prism adaptation procedure. Finally, we conclude with methodological recommendations that should permit optimal use of the procedure in application.

1. Empirical observations

When a person first looks through wedge prisms that optically displace the visual field, for example 10° in the rightward direction, the person may have little feeling that anything is out of the ordinary, but then he/she experiences surprising difficulty in perceptual-motor tasks (i.e. direct effects of prism exposure). For example, pointing toward a visual target produces error to the right of target position, where the target is seen to be located. Performance error is gradually reduced to pre-exposure levels as the person makes repeated attempts at target pointing (error reduction phase). Adaptation to the prismatic displacement occurs. And, when the prisms are removed the person experiences surprising errors in the opposite direction, to the left of the target! This negative aftereffect of prism exposure demonstrates a persistence of adaptation acquired during exposure. Thus, the basic prism adaptation procedure simply involves (1) pre-exposure baseline measurement of performance, (2) active exposure to prismatic displacement to produce adaptation, and (3) post-exposure compensatory aftereffect measurement of adaptation persistence. Is this all there is to prism adaptation? Prism adaptation is deceptively simple. In fact, there are many nuances of prism adaptation in both method and results.

First, the initial direct effect of the prisms at the beginning of exposure is not directly predictable by the magnitude of prismatic displacement. While direct effects are in the direction of displacement and roughly proportional to the displacement, the amount of direct effect may not even nearly match the magnitude of displacement. For example, objects in a well-structured visual field appear to be displaced only about 40 percent of the prismatic displacement even though participants remain stationary and see no part of their body: there is an immediate correction effect (Rock et al., 1966). Another modulation of direct effect is the straight-ahead shift (Harris, 1974) where cognitive judgment of straight ahead tends to be centered in the optically displaced structured visual field such that straight ahead objects tend to be judged closer to straight ahead than they appear in spite of the optical displacement.

A third initial factor affecting direct effect is visual capture (Hay et al., 1965; Tastevin, 1937) where the stationary hand tends to be felt to be located near where it looks to be located. A final factor affecting direct effect is first trial 'adaptation' (Redding and Wallace, 2003b, 2004a). The effect of the prisms on the first exposure trial is usually much less than would be expected by the amount of prismatic displacement, even if the pointing hand is only visible at the end of movement and cannot be visually guided to the target. For example, error in target pointing may be only 4 deg to the right for a 10 deg rightward prismatic displacement: only 40 percent of the displacement. Thus, the immediate direct effect of prismatic displacement on experience and performance is surprisingly complex.