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Development of a new computerized prism adaptation procedure for visuo-spatial neglect

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HIGHLIGHTS

- We have developed a new computerized prism adaptation procedure (Peg-the-Mole, PTM).
- PTM is easily standardized and could be carried out at home by patients.
- PTM and the typical prism procedure were equally effective at similar doses.
- PTM has a greater potential for increased treatment adherence and intensity.
- PTM may be a promising alternative rehabilitation technique for neglect.

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ABSTRACT

Background: Prism adaptation (PA) is a promising rehabilitation technique for visuo-spatial neglect. However, PA effects are often inconsistent across studies and the clinical application of this technique has been limited. The purpose of the present studies was to validate an easily standardized, home-friendly, and game-like PA technique (Peg-the-Mole) with healthy participants as a first step toward clinical development.
New method: In study 1, we used Peg-the-Mole with 32 participants wearing prism or sham goggles to investigate whether this procedure can induce significant after-effects on midline judgment and pointing tasks. In study 2, we compared Peg-the-Mole to a typical PA protocol in 42 participants for after-effects and level of enjoyment and to determine if the after-effects generalize to a throwing task.
Results and comparison with existing method: Study 1 showed that Peg-the-Mole induced significant after-effects on all outcome measures. Study 2 demonstrated that after-effects induced by Peg-the-Mole were equivalent to those induced by the typical PA procedure on all outcome measures. Peg-the-Mole was rated as more enjoyable than the typical procedure.
Conclusions: Peg-the-Mole is a new computerized PA procedure that can be easily standardized and successfully used to induce significant after-effects. The present findings demonstrate that alterations can be made to the typical PA procedure to make it easier to use and more enjoyable, factors that could increase treatment availability, adherence and intensity.

Abbreviations: PA, prism adaptation; PTM, Peg-the-Mole.

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1. Introduction

Visuo-spatial neglect is a common disorder after right-hemisphere stroke that is characterized by a failure to orient, attend or respond to stimuli on the contralesional side (Heilman et al., 1993). This disorder is often chronic (Karnath et al., 2011) and has been linked to poor rehabilitation outcomes, making it an important target for rehabilitation (Gillen et al., 2005; Katz et al., 1999; Paolucci et al., 2001). Visual scanning training was suggested as the practice standard for neglect (Cicerone et al., 2011). A major limitation of this treatment approach is the fact that it requires long-term intensive treatment, using specialized equipment. This approach also depends upon the development of patient-directed strategies, which might be difficult to use in patients with neglect who are often unaware of their own deficits (Appelros et al., 2003).

One promising alternative treatment option for neglect that involves less strategic processing is prism adaptation (PA; Kerkhoff and Schenk, 2012; Luauté et al., 2006; Newport and Schenk, 2012). The typical PA procedure involves the repetition of pointing movements toward visual targets (e.g., ranging from small circular targets to vertical lines) while being exposed to prism mounted goggles that shift the visual field rightward by a set number of degrees (usually 10–15 degrees; e.g., Rossetti et al., 1998; Mizuno et al., 2011). During prism exposure, rightward pointing errors are initially observed as a result of the rightward optical deviation. Adaptation to prisms that occurs throughout the exposure task results in a progressive reduction in pointing errors. Previous research suggests that two main sensori-motor processes are involved in the adaptation to prism goggles: recalibration (i.e., the conscious and strategic effort to correct pointing errors) and realignment (i.e., the unconscious and gradual remapping of the proprioceptive and visual spatial maps; Redding and Wallace, 2006). Once prisms are removed, patients can exhibit after-effects (e.g., a leftward shift in pointing movements from pre- to post-prism exposure) associated with a reduction in the symptoms of neglect (e.g., Rossetti et al., 1998).

A typical PA procedure was successfully used to treat neglect in patients in a seminal study by Rossetti and colleagues (1998) who demonstrated pointing after-effects as well as improvements on neuropsychological tests lasting for at least 2 h in patients exposed to prisms. Other studies have shown longer lasting after-effects from 24 h up to four days after a single PA exposure phase (Farnè et al., 2002; Pisella et al., 2002). Generalization of after-effects to visuo-motor (Farnè et al., 2002) and visuo-verbal tasks (Farnè et al., 2002; Serino et al., 2006), as well as to other measures such as wheelchair navigation (Jacquin-Courtois et al., 2008) and postural control (Tilikete et al., 2001) has also been reported in patients with neglect, although not all studies see positive effects. For example, Turton and colleagues (2010) as well as Nys and colleagues (2008) did not observe differential effects of PA treatment when compared to a sham treatment on various tests of neglect in stroke patients.

In healthy participants, preventing self-corrections in pointing movements during prism exposure has been shown to be crucial for the development of after-effects (Redding and Wallace, 1996). Similarly, minimizing conscious strategic control of the pointing movements (e.g., by using an occlusion board or by gradually increasing the optical deviation during prism exposure so that participants remain unaware of the spatial distortion) has been shown to induce larger after-effects (Michel et al., 2007) and facilitate the generalization of these after-effects in space (Redding and Wallace, 2006). These findings raise the possibility that the inconsistent PA effects in the patient literature might be partly explained by the set-up used in some studies allowing for self-corrections in pointing movements. It is important to note that manuscripts often do not include enough details to allow the reader to verify whether sufficient effort was made to prevent self-correction in pointing movements during the exposure task (e.g., Rousseaux et al., 2006). Even when only the terminal part of the pointing movements can be seen by participants, it is still possible for them to self-correct their movements before reaching the targets, particularly when these targets are not removed when the pointing movements are too slow or when there is no feedback or training to encourage speeded responses without correction.

The exposure task in the typical PA procedure that has been used in healthy participants and in patient studies also has important limitations preventing its clinical application. First, exposure sessions have to be conducted in research or hospital settings under the supervision of a therapist to ensure the correct procedure and prevent self-corrections. The need for daily supervision limits the possibility of establishing the PA procedure in patients' homes, which could optimize success of treatment given that repeated PA sessions are necessary for long-lasting improvements (see Newport and Schenk, 2012). The necessity to go to a treatment facility for every PA session is an important factor limiting the intensity of the treatment and its potential therapeutic effect. Furthermore, the typical PA procedure can be rather tedious, which might be an important issue for treatment adherence, even if the necessary procedures could be adapted to home use.

To solve these important issues affecting treatment adherence, intensity, and effectiveness, we have developed a PA procedure that is easily standardized, minimizes conscious self-corrections in pointing movements, is more enjoyable and could be carried out at home by patients without the need for daily supervision. As a first step, study 1 was conducted to determine if the new home-friendly, game-like PA procedure called Peg-the-Mole (PTM) could induce significant after-effects in healthy adults. The possibility of increasing the number of targets used during the exposure phase to make the procedure less repetitive without altering the magnitude of the after-effects was also explored. Study 2 was subsequently conducted to assess the validity of the PTM procedure by comparing the after-effects induced by PTM with the after-effects induced by a typical PA procedure. The generalization of the after-effects to a more functional task was also investigated. Finally, the level of enjoyment experienced by participants during the use of both procedures was compared. Overall, the findings of these two studies contribute to the validation of the PTM procedure in healthy participants, which is the first step toward the use of this procedure in patients to treat symptoms of neglect.

2. Study 1

2.1. Method

2.1.1. Hypothesis and design

In study 1, we tested the following hypothesis: Responding to PTM (while wearing prism goggles) will be effective in inducing significant after-effects when compared to a sham adaptation procedure. In this study, we also wanted to explore whether the use of a different number of targets ($n = 3$ vs. $n = 9$) during the exposure task will induce significant and equivalent magnitude of after-effects due to the generalization of the after-effects in space. This question is clinically relevant as the possibility of altering the number of targets when using PTM in patients might make the procedure more enjoyable and potentially contribute to increase treatment adherence.

This study included three groups of participants: (1) prism exposure using PTM with three targets; (2) prism exposure using PTM with nine targets; and (3) sham exposure with three targets. Only one control (i.e., sham) group was used as a full-factorial design was planned for study 2.