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Sensorimotor plasticity in response to predictable visual stimuli could correct the signs of spatial neglect

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Dear Editor. To interact with the visual environment and successfully guide motor behaviors, we must construct internal representations of the world. When possible, these dynamic representations are informed by learned spatial and temporal patterns, allowing us to anticipate the appearance of certain stimuli and respond efficiently [1]. The parietal cortex is one brain region that supports the building of these sensorimotor priority maps and coordinates appropriate responses [2,3]. Furthermore, these internal maps rely on spatial remapping and working memory during visual exploration to update and maintain a stable representation of our environment across eye movements, linking the visual information gathered at each fixation [4,5].

In this study, we presented healthy older adults with a predictable or randomly appearing visual stimulus to investigate the plasticity of the visual–manual response after learning a stimulus sequence. We hypothesized that with repeated performance of the predictable sequence, participants would show improved sensorimotor reactivity based on construction of internal representations of the stimulus pattern, thereby allowing for reduced reaction times as compared with the initial performance and the non-predictable condition. Such improvement could demonstrate the viability of simple visual motor training for individuals with attentional or motor disorders due in part to parietal cortex lesions, such as spatial neglect [6,7].

In total, 26 participants (16 females, mean age 55.9 [SD 7.8] years) gave written consent validated by the University Hospital of Geneva ethical committee and were screened for cognitive dysfunction with the Montreal Cognitive Assessment (MoCA, range 0–30; www.mocatest.org) before the experiment (mean score 27.58 [SD 1.33], cutoff <26). All had normal or corrected-to-normal vision and no history or evidence of neurological or psychiatric disorder.

Participants were placed in front of a computer touch screen (Microsoft Surface) on which a sequence of blue and red dots appeared at 4 possible locations arranged horizontally on the screen. They were presented with a predictable or randomly appearing visual stimulus and instructed to touch its location on the screen when a red (vs blue) dot appeared. Each dot appeared for 1000 msec with a 1000-msec inter-stimulus interval. There were 2 presentation conditions: a predictable condition in which the dots appeared from right to left and a random condition in which the dots could appear in any order. The participants were instructed to touch all red dots rapidly and precisely with their index finger on their dominant hand and to keep their hand on the space bar between trials. Each block consisted of 300 total dots (200 red, 100 blue) and lasted 10 min.

Participants performed both conditions (in counterbalanced order) once a day for 1 week. Reaction time (RT) was measured as the interval (in seconds) from the appearance of each dot until the participant touched the screen. We excluded trials in which the participant did not touch within an area of 100 $pixels^2$ of the target dot or did not respond within 1000 msec. Mean RT was analyzed by ANOVA with SPSS 25 (IBM Corp.), with repeated measures of condition (predictable and random) and day (1 to 5). $P<0.05$ was considered statistically significant. Greenhouse-Geisser–corrected degrees of freedom were used when Mauchly's test of sphericity indicated unequal variance.

The condition by day analysis revealed a significant effect of day ($F(3.1,76.9)=14.4$, $p<0.05$, $\eta^2=0.37$) and a non-significant interaction between day and condition ($F(1.9,46.8)=2.7$, $p=0.08$, $\eta^2=0.10$). However, 4 participants were unable to show improvement even in the predictable condition (i.e., increased RT from day 1 to day 5), and their data were excluded from subsequent analyses. The analysis of the remaining 22 participants showed a significant effect of day ($F(4,84)=12.5$, $p<0.05$, $\eta^2=0.37$), and condition ($F(1,21)=5.0$, $p<0.05$, $\eta^2=0.19$), and a day-by-condition interaction ($F(1.8,37.1)=3.8$, $p<0.05$, $\eta^2=0.15$). The effect of day showed a decrease in RT from day 1 (0.836 [SD 0.012] sec) to day 5 (0.787 [SD 0.014] sec), whereas the effect of condition showed faster RTs for the predictable than random condition (0.793 [SD 0.016]) vs 0.823 [SD 0.013] sec). The day-by-condition interaction (Fig. 1) showed that for the predictable condition, participants were able to decrease their RT after a single day (day 1 vs day 2, $t(21)=4.0$, $p<0.05$), whereas in the random condition, a significant decrease was not observed until day 5 ($t(21)=2.9$, $p<0.05$).

In this study, sensorimotor plasticity in healthy participants was demonstrated in a visual–manual task that required learning a spatiotemporal pattern of visual stimuli. By using spatial remapping and working memory, participants were able to integrate visual information across trials and practice days to build an accurate representation of the predictable task stimuli and use this internal model to stimulate motor plasticity (i.e., by reducing response times). Furthermore, this improvement occurred earlier and to a greater degree than general-task practice effects observed in the random condition that might relate to greater familiarity with the tasks overall or attentional control. Although eye movements were not recorded, the expectation of the dot appearance in the predictable condition likely allowed participants to look to its location more quickly, identify the target color, and make the manual response more quickly. Thus, learning the predictable stimulus pattern led to sensorimotor plasticity by putatively biasing the responsiveness of the appropriate visual and motor neurons during the task. Additionally, the inclusion of "no-go" stimuli ensured that the participants were not simply programming a series of hand movements but had to integrate the new visual information for each dot appearance with the internal expectation based on the predictable sequence, presumably relying on spatial remapping and hand–eye coordination mechanisms in the posterior parietal cortex [3].

Recently, several studies have suggested a link between remapping and spatial neglect, a complex disorder often resulting from lesions affecting the parietal cortex and its underlying white-matter tracts and characterized by an inability to orient or respond to contralesional stimuli (for review see [6]). Spatial neglect negatively affects daily life for patients and caregivers and although many rehabilitation techniques show promise, studies often fail to demonstrate consistent and lasting improvements in behavior [8]. Hence, the development of additional targeted approaches could be beneficial. In a previous study involving a task similar to the current paradigm but with a button press response [7], patients with spatial neglect due to parietal lesions were unable to learn the predictable pattern of stimuli or improve their performance within a single session. Such patients have demonstrated specific spatial working memory problems in other studies [9-11]. Of note, 4 of our healthy participants also did not reduce their reaction time in the predictable condition, and although we did not collect other measures of executive function or attentional control to speculate on why they did not learn from the sensorimotor training, it may be due to general attention deficits or a lack of motivation across the multiple sessions.

Nonetheless, given the ability of most healthy older adults in the current task to learn the predictable sensorimotor pattern and perform more efficiently over time, future research using this paradigm may show that certain neglect patients can benefit from a similar plasticity and recalibration of their visual-motor maps. If so, this simple paradigm could supplement existing rehabilitation approaches such as visual scanning training or prism adaptation [8] depending on the individual's needs and abilities, to better alleviate persistent spatial attention deficits.

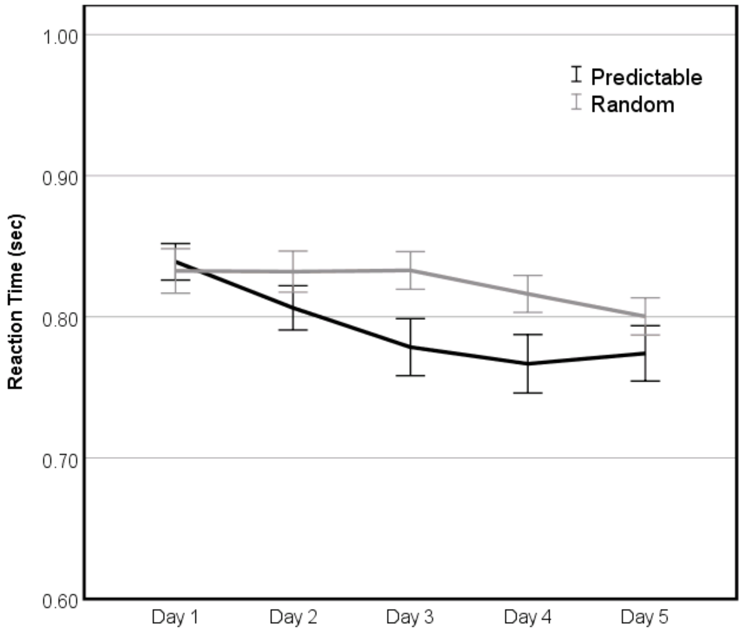

Figure 1. Mean reaction time (seconds) in the predictable (black line) and random (gray line) conditions from day 1 to day 5.

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Conflict of interest. None declared.

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