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Research Report

Neural plasticity underlying visual perceptual learning in aging

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ABSTRACT

Healthy aging is associated with a decline in basic perceptual abilities, as well as higher-level cognitive functions such as working memory. In a recent perceptual training study using moving sweeps of Gabor stimuli, Berry et al. (2010) observed that older adults significantly improved discrimination abilities on the most challenging perceptual tasks that presented paired sweeps at rapid rates of 5 and 10 Hz. Berry et al. further showed that this perceptual training engendered transfer-of-benefit to an untrained working memory task. Here, we investigated the neural underpinnings of the improvements in these perceptual tasks, as assessed by event-related potential (ERP) recordings. Early visual ERP components time-locked to stimulus onset were compared pre- and post-training, as well as relative to a no-contact control group. The visual N1 and N2 components were significantly enhanced after training, and the N1 change correlated with improvements in perceptual discrimination on the task. Further, the change observed for the N1 and N2 was associated with the rapidity of the perceptual challenge; the visual N1 (120–150 ms) was enhanced post-training for 10 Hz sweep pairs, while the N2 (240–280 ms) was enhanced for the 5 Hz sweep pairs. We speculate that these observed post-training neural enhancements reflect improvements by older adults in the allocation of attention that is required to accurately dissociate perceptually overlapping stimuli when presented in rapid sequence.

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Contents

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1. Introduction

It is well documented that even healthy aging is associated with a decline in cognitive abilities in the domains of perception, attention and working memory (WM) (Craik and Salthouse, 2000; Schneider and Pichora-Fuller, 2000). Aspects of age-related declines in WM have been related to primary deficits in perception (Craik and Salthouse, 2000; Wigfield et al., 1994), although studies that successfully parse between perception and WM impairments are scarce. Furthermore, while studies have shown perceptual learning to occur in both younger (Ball and Sekuler, 1987; Schoups et al., 1995) and older adults (Fahle and Daum, 1997; Alain et al., 2001), there is little evidence of transfer of benefits to other cognitive functions such as WM. Using ERP recordings, we investigate the sensory cortical plasticity underlying perceptual learning in healthy aging, and assess how this relates to behavioral gains in perceptual discrimination on the task itself and concomitant gains in WM on an untrained task.

In a recent study from our lab, Berry et al. (2010) demonstrated that visual perceptual abilities of older adults can be enhanced by adaptive perceptual discrimination training. Participants trained on discriminations of sweeping Gabor patterns that involved distinguishing the sweep directions of two sweeps (inward contraction vs. outward expansion) presented rapidly as a pair of stimuli. This *Sweep Seeker* training was adaptive to performance accuracy, thus presenting more challenging sweep rates immediately after successful performance and slowed sweep rates after failed performance. Berry et al. evaluated post vs. pre-training perceptual improvements using a non-adaptive assessment that presented sweep pairs at fixed rates of 2.5 Hz, 5 Hz and 10 Hz (the fixed-speed test), and found significant benefit only on the most rapidly presented challenging sweep rates of 5 Hz and 10 Hz. This result supported previous evidence of perceptual learning in older adults with challenging discrimination practice (Fahle and Daum, 1997). Uniquely, Berry et al. also showed that this training benefitted performance on an untrained perceptual task and an untrained WM delayed-recognition task that both used dot motion kinematogram stimuli.

Thus, the Berry et al. (2010) study highlighted the benefits of challenging perceptual learning in aging on perception abilities, as well as higher order cognitive function such as WM. To follow up on these findings, here we explore the neural mechanisms by which older individuals learned to better perform on these challenging perceptual discriminations of sweep pairs presented at such rapid rates of 5 Hz and 10 Hz in the fixed-speed test.

The fixed-speed perceptual assessment presented single sweep (ss) and double sweep (ds) gabor patch stimuli in separate blocks (Fig. 1A). In either block, stimuli were randomized to appear at three different stimulus durations of 50 ms, 100 ms or 200 ms. In the ds block these durations respectively corresponded to presentation rates of 10 Hz, 5 Hz and 2.5 Hz, as the inter-stimulus intervals (isi) matched the stimulus durations. Henceforth, these stimuli are abbreviated as ss50, ss100, ss200 and ds50, ds100, ds200. For both single or double sweep trials, participants made speeded discriminations on whether each presented sweep was expanding or contracting. The fixed-speed assessment was performed at two sessions, T1 and T2 that were 3–5 weeks apart, by two experimental groups consisting of 15 older adults who trained on 10 h of visual sweep discrimination and 15 older adults who engaged in no training. Ten hours of training was chosen as a feasible training dose for participants for which there would be high probability of full compliance over the 3–5 weeks of training with 40 min of training per session. Also, based on prior studies in the literature, we estimated that approximately ten hours on a training module would engender sufficient learning, and training-related benefits may plateau (Green and Bavelier, 2003; Dahlin et al., 2008; Li et al., 2008).

On the fixed speed test, Berry et al. (2010) observed that performance accuracy significantly improved for the challenging ds50 and ds100 stimuli post-training. Here, we analyzed the ERP responses to these stimuli to specifically assess the training-related neural correlates of these behavioral effects. We hypothesized that neuroplasticity in visual processing would be observed for the ds50 and ds100 stimuli, in accordance with the performance improvements that were previously reported. Also,