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Reading speed in the peripheral visual field of older adults: Does it benefit from perceptual learning?

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ABSTRACT

Enhancing reading ability in peripheral vision is important for the rehabilitation of people with central-visual-field loss from age-related macular degeneration (AMD). Previous research has shown that perceptual learning, based on a trigram letter-recognition task, improved peripheral reading speed among normally-sighted young adults (Chung, Legge, & Cheung, 2004). Here we ask whether the same happens in older adults in an age range more typical of the onset of AMD. Eighteen normally-sighted subjects, aged 55–76 years, were randomly assigned to training or control groups. Visual-span profiles (plots of letter-recognition accuracy as a function of horizontal letter position) and RSVP reading speeds were measured at 10° above and below fixation during pre- and post-tests for all subjects. Training consisted of repeated measurements of visual-span profiles at 10° below fixation, in four daily sessions. The control subjects did not receive any training. Perceptual learning enlarged the visual spans in both trained (lower) and untrained (upper) visual fields. Reading speed improved in the trained field by 60% when the trained print size was used. The training benefits for these older subjects were weaker than the training benefits for young adults found by Chung et al. Despite the weaker training benefits, perceptual learning remains a potential option for low-vision reading rehabilitation among older adults.

1. Introduction

Age-related macular degeneration (AMD) afflicts approximately one out of ten Americans aged 80 years and older (Eye Disease Prevalence Research Group, 2004). Advanced AMD often results in bilateral central scotomas, damaging the fovea. AMD patients with central scotomas have to rely on their peripheral vision for daily visual functions such as reading. Since normal peripheral reading is difficult and slow (Chung, Mansfield, & Legge, 1998), it is not surprising that AMD patients with central scotomas always have reduced reading performance (Faye, 1984; Fine & Peli, 1995; Fletcher, Schuchard, & Watson, 1999; Legge, Ross, Isenberg, & LaMay, 1992; Legge, Rubin, Pelli, & Schleske, 1985). The current study investigated the possibility of improving peripheral reading performance in a group of normally sighted older people using perceptual learning with a simple trigram letter-recognition task.

Conventional rehabilitation for AMD patients with central scotomas often includes training on eccentric viewing and magnifier usage (Goodrich & Mehr, 1986; Goodrich et al., 2004; Holcomb & Goodrich, 1976; Nilsson & Nilsson, 1986; Stelmack, Massof, & Stelmack, 2004). Eccentric-viewing and magnifier-usage training has been shown to improve reading performance among AMD patients (Cheong, Lovie-Kitchin, Bowers, & Brown, 2005; Goodrich et al., 2004; Nilsson, Frennesson, & Nilsson, 1998, 2003). These rehabilitation efforts focus on teaching the patients strategies to deal with their vision loss, and how to use their low-vision aids effectively.

Alternatively, the perceptual system can be modified or "retuned" through perceptual learning (see Gibson (1963) and Goldstone (1998) for reviews). Gibson (1963, p. 29) defined perceptual learning as "[any] relatively permanent and consistent change in the perception of a stimulus array, following practice or experience with this array." Some researchers have shown that low-vision patients may benefit from perceptual learning (Chung, Legge, & Cheung, 2004; Legge et al., 2008; Sommerhalder et al., 2003).

Recent research findings suggest that letter recognition imposes a perceptual limit on word recognition and reading speed (Legge, Mansfield, & Chung, 2001; Legge et al., 2007; Pelli, Farell, & Moore, 2003; Pelli & Tillman, 2007). Visual span is a spatial property of the visual field defined as the number of characters that can be recognized without moving the eyes (Legge, Ahn, Klitz, & Luebker, 1997; O'Regan, 1990). Since shrinkage of the visual span has been shown to limit normal peripheral reading (Legge et al., 2001), peripheral

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reading speed may improve if the size of the peripheral visual span is enlarged.

Chung et al. (2004) showed that perceptual learning enlarged the visual-span size in normal peripheral vision in a group of young adults. They also found a corresponding improvement in reading speed. Chung et al.'s study raised the possibility of benefits of perceptual learning in improving reading performance among AMD patients with central scotomas. However, Chung et al.'s study was conducted with young normally-sighted adults, whereas the onset of AMD typically occurs after 60 years of age.

Perceptual learning in vision has been found to have neural correlates in the visual cortex (Karni & Sagi, 1991; Neary, Anand, & Hotson, 2005; Schoups, Vogels, Qian, & Orban, 2001; Schwartz, Maquet, & Frith, 2002; Song et al., 2005; Yang & Maunsell, 2004). Recent research has suggested that plasticity in the perceptual system decreases with aging (Smirnakis et al., 2005; Sunness, Liu, & Yantis, 2004). If perceptual learning in the visual system depends on reorganization in visual cortex, decreased cortical plasticity in aging could have adverse implications for the potential benefits of visual perceptual learning in older adults.

In this study, we used a similar perceptual-learning paradigm as in Chung, Legge and Cheung's study and report results from a group of older subjects. If similar learning effects can be demonstrated in older normally-sighted subjects, there would be an increased likelihood that such perceptual learning could be used in low-vision reading rehabilitation. On the other hand, reduced perceptual learning in this older group could reveal decreased plasticity in the visual system with aging.

2. Methods

2.1. Subjects

Eighteen normally-sighted adults (10 females and 8 males) aged 55–76 years were recruited from the University of Minnesota Retirees Volunteer Center to participate in this study. Refractive errors were corrected using trial lenses. Our subjects were randomly assigned to a training group (T1 to T9) and an age-matched control group (C1 to C9). Informed consent was obtained from each subject before the experiment. Subjects received monetary compensation for their time. The protocol of this study followed the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board of the University of Minnesota.

Prior to the experiments, each subject was tested on four clinical vision tests: (a) the Lighthouse Distance Visual Acuity Test (Optelec US Inc., Massachusetts, USA), (b) the Pelli-Robson Contrast Sensitivity Test (Haag-Streit UK, Essex UK) (Pelli, Robson, & Wilkins, 1988), (c) the Lighthouse Near Visual Acuity Test (Optelec US Inc., Massachusetts, USA), and (d) the MNREAD Reading Acuity Test (Optelec US Inc., Massachusetts, USA) (Mansfield, Ahn, Legge, & Luebker, 1993; Mansfield & Legge, 2007). All tests were done binocularly.

Subjects were tested on the MNREAD in both regular and reversed contrast polarities. The three summary measures from the MNREAD test, reading acuity, critical print size and maximum reading speed, were calculated using the method described by Cheung, Kallie, Legge, and Cheong (2008). Table 1 summarizes the results of the clinical vision tests. We found no significant difference (uncorrected $ps > 0.05$) between the control and the training groups in age and the measures from the clinical vision tests.

2.2. Experimental design

The basic design of the current experiment was similar to that of Chung et al. (2004). Pre- and post-tests for both the control (C1 to C9) and the training (T1 to T9) subjects consisted of measurements of visual-span profiles and RSVP reading speeds at 10° eccentricity in both upper and lower visual fields. Schuchard, Naseer, and de Castro (1999) reported a median scotoma height of 18° among 255 patients (see Cheung and Legge (2005) for a review). If the scotoma was approximately centered at the fovea, a retinal location near the scotoma boundary that could be used for reading in these patients would be approximately 10° away from the fovea. Taking 10° eccentricity as representative of a field location used for reading in AMD, we tested our subjects at 10° eccentricity in the upper and lower visual fields. These same retinal locations were also used in the study by Chung et al. (2004).

The training subjects participated in four consecutive days of training between the pre- and post-tests. Training consisted of repeated measurements of visual-span profiles at 10° eccentricity in the lower visual field, the same as one of the two retinal locations used in the pre- and post-tests. No feedback was provided during training. Pre- and post-tests were six days apart for both the training subjects and the control subjects, who did not receive any training. We also tested the untrained upper visual field in both pre- and post-tests to assess whether training effects would transfer to an untrained retinal location.

2.3. Visual-span profile measurements

Visual-span profiles were measured using the methods described in previous studies (Chung et al., 2004; Legge et al., 2001,

Table 1
Summary table of clinical test results. *W* is the Wilcoxon two-sample rank sum statistic[a] (Wilcoxon, 1945) and is the sum of the ranks for the control group with the minimum (sum of 1–9, i.e., 45) subtracted. *p* is the two-sided *p*-value associated with *W*.

	Control		Training		*W*	*p*
	Mean (SD)	Median	Mean (SD)	Median		
Age (year)	65.4 (7.6)	68	65.6 (8.2)	64	37	0.790
Distance visual acuity (log MAR)	−0.11 (0.11)	−0.12	−0.17 (0.06)	−0.20	56.5	0.169
Near visual acuity (log MAR)	0.00 (0.10)	−0.02	−0.01 (0.09)	0.00	39.5	0.965
Log contrast sensitivity	1.90 (0.07)	1.88	1.93 (0.07)	1.95	30	0.347
MNREAD – regular polarity						
Reading acuity (log MAR)	−0.06 (0.11)	−0.11	−0.14 (0.13)	−0.14	54	0.251
Critical print size (log MAR)	0.18 (0.17)	0.15	0.13 (0.15)	0.12	45	0.730
Maximum reading speed (wpm)	177.07 (20.11)	177.84	194.04 (25.38)	196.52	26	0.222
MNREAD – reversed polarity						
Reading acuity (log MAR)	−0.05 (0.15)	−0.02	−0.13 (0.12)	−0.16	52	0.331
Critical print size (log MAR)	0.18 (0.13)	0.17	0.08 (0.14)	0.03	60	0.094
Maximum reading speed (wpm)	170.26 (19.34)	171.00	186.58 (24.40)	188.97	26	0.222

[a] Due to our relatively small sample size and the possible violation of the normality assumption required for a *t* test, we decided to use its nonparametric counterpart, the Wilcoxon rank sum test (Wilcoxon, 1945).