Training the Adult Amblyopic Eye with “Perceptual Learning” after Vision Loss in the Non-Amblyopic Eye

ABSTRACT

We recently reported (Fronius et al., 2005) acuity development in the amblyopic eye of a 60-year-old patient after loss of vision in her non-amblyopic eye. Here, we focus on the training that we implemented, based on new insights from psychophysical procedures aiming at functional visual improvement of adults (“perceptual learning” (Levi & Polat, 1996; Polat et al., 2004)). We alternately used the following procedures: grating acuity (Teller-Cards); contrast sensitivity (Vistech-Charts); two spatial localization tests (vertical alignment, pointing); and labyrinth patterns for a eye-hand coordination exercise. One month without intervention was followed by six months of training and two blocks of pleoptic treatment. Clinical parameters were assessed monthly.

Besides acuity gain, we observed enhanced grating resolution and contrast sensitivity, decreased alignment distortions, pointing shifts, mainly after pleoptics, and more efficient labyrinth tracing. A questionnaire reflected the patient’s perception of the changes.

These data confirm the plasticity of the adult amblyopic system, be it spontaneous due to the loss of the non-amblyopic eye or caused by the intervention or both. Further experience is necessary to isolate the role of the intervention. Our results also underline the limitation of adult plasticity, emphasizing the importance of early diagnosis and treatment of amblyopia.

KEYWORDS

Amblyopia treatment; adult plasticity; perceptual learning, spatial localization; visual acuity

INTRODUCTION

Prospective data on the function of amblyopic eyes after loss of vision in their fellow non-amblyopic eyes in adulthood are rare. Although spontaneous improvement may occur (El Mallah et al., 2000), the prognosis is unfavourable (Rahi et al., 2002), especially in strabismic amblyopia with eccentric fixation (Vereecken & Brabant, 1984). Reports about neural plasticity in adult amblyopia being enhanced by means of psychophysical training (“perceptual
learning” (Levi & Polat, 1996; Polat et al., 2004)) raised hope for such patients. We implemented a training program for a 60-year-old strabismic amblyope with low acuity and eccentric fixation who lost the function of her non-amblyopic left eye due to central artery occlusion. Data on her clinical condition and its development over several months before and during this intervention, especially the gain of visual acuity by 3–4 lines, have already been reported (Fronius et al., 2005). These data were discussed in the context of the literature on spontaneous acuity improvement after loss of the non-amblyopic eye. Here, we present novel details of the psychophysical training procedure and of the development of the trained visual functions.

MATERIALS AND METHODS

The patient reported strabismus “from birth” and a “lazy eye.” She received optical correction, but only a brief, irregular period of patching in childhood. Her initially dominant eye was left with hand movement perception after central artery occlusion.

Acuity testing took place with unchanged glasses (R,L +0.75 diopters, near add. + 2.5) throughout our testing period (Fronius et al., 2005). The training was based on material available in our department, addressing various visual functions. After two acuity tests during one month without intervention, training was performed twice a week, each session lasting about 1 hour, and alternating between different procedures. The tasks required attention. Feedback was given, except for the first run of each test in each session. Teller Acuity Cards trained spatial resolution, the threshold being assessed several times in each session. The patient indicated verbally, after unrestricted viewing time, on which side of the card she perceived the grating. The Vistech Contrast Sensitivity Chart (type B) was used for training. The patient specified the line orientation of the stimuli at which the tester pointed and received feedback. The chart was randomly rotated to avoid memory effects. For the same reason, the final outcome after training was tested with the type A chart (identical stimuli, only a different sequence of the line orientations within each row), unknown to the patient. Two procedures trained spatial localization: In a vertical alignment test (Fronius et al., 2004), the patient aligned a central test line with two vertically arranged reference stimuli. In the eye-hand coordination test, the patient pointed to the memorized position of a stimulus briefly presented on a computer monitor, recording pointing deviations by means of TouchScreen-technology (Fronius, unpublished method). For eye-hand coordination exercise at home, the patient traced labyrinth patterns of varying complexity with a felt-tip pen.

Six months of psychophysical training were followed by two blocks (8 sessions each) of pleoptic treatment (Cüppers euthyscope procedure (Cüppers, 1956)), while monitoring of all visual functions was continued. All procedures were carried out in accordance with the Declaration of Helsinki.

RESULTS

Visual Acuity and Contrast Sensitivity

The patient’s initial acuity in the amblyopic eye was 0.1 (logMAR 1.0) for single and 0.063 (logMAR 1.2) for crowded optotypes (Landolt rings). It gradually increased during 8–9 months of intervention (see Fronius et al., 2005 for details): to 0.25 (logMAR 0.6) for single optotypes and to 0.125 (logMAR 0.9) for crowded optotypes. Grating acuity gradually improved from 9.8 to 19.6 and 26 cycles/degree during the first 5 months of the intervention. Converted, this corresponded to decimal values of 1.0 (logMAR 0) to 1.33 (logMAR –0.12). The discrepancy with the maximum Landolt ring acuity may be due to the overestimation of acuity in strabismic amblyopia with grating stimuli, but a contribution of the edge artefact of the Teller cards cannot be excluded. Contrast sensitivity, tested after 6 months of training, was enhanced for several spatial frequencies (Fig. 1A).

Spatial Localization

The sensory spatial localization initially showed a temporal misalignment of the central stimulus of 9.55 minarc (SD 8.15), which gradually decreased to 4.67 minarc (SD 6.29), Mann-Whitney-U-test: p = 0.02. Pointing revealed interesting changes, especially after pleoptics (Fig. 2): after an initial temporal error of 1.17 degrees (SD 0.57), which remained relatively stable during psychophysical training, sudden shifts occurred shortly after both blocks of pleoptics (Mann-Whitney-U-test, p ≤ 0.0001); these were the only two occasions when pointing errors in the opposite, nasal direction were observed. For comparison, the range of pointing errors was between 0 and 0.57 degrees.

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FIGURE 1  Panel A: Two contrast sensitivity assessments with different types of the Vistech-chart, at the beginning (broken line) and the end of the psychophysical training (solid line). Panel B: Labyrinth pattern tracing. First weeks: simple patterns, poorly traced (6 patterns on the left); later: complex pattern, successfully traced.

(mean 0.11 SD 0.21) in adults with normal vision tested with this set-up (Fronius, unpublished data). Pointing errors are not the rule in amblyopes with comitant strabismus (Von Noorden & Campos, 2002), but errors of up to 3.8 degrees were observed in patients with large-angle strabismus tested with a slightly different procedure (Fronius & Sireteanu, 1994). The remarkable findings in Fig. 2 were the sudden pointing shifts after pleoptics.

Small *labyrinth* patterns were traced with difficulty during the first weeks (Fig. 1B, the 6 labyrinths on the left). Later, tracing even more complex labyrinth patterns became more certain (Fig. 1B, right labyrinth).
Pointing data during psychophysical training and after two blocks of pleoptics (pleopt. I, pleopt. II). After 3 sessions without feedback (baseline), each session comprised first one cycle without, then 1–2 cycles with feedback. Data shown were means from the first cycle of each session. Error bars: standard deviations.

A questionnaire applied several times reflected the patient’s subjective perception of the changes (Table 1): hardly any difference in reading or grasping, but an improvement of spatial orientation.

**DISCUSSION**

Following accounts of plasticity in “bi-ocular” adult amblyopes due to perceptual learning (Levi & Polat,

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**TABLE 1**  Patient’s subjective evaluation of her visual capacities during the training period

<table>
<thead>
<tr>
<th>Spatial orientation</th>
<th>Test intervals (months of supervision)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3.25</th>
<th>5.75</th>
<th>6.75</th>
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<tbody>
<tr>
<td>Very difficult</td>
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<tr>
<td>Difficult</td>
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<td></td>
</tr>
<tr>
<td>Neither difficult nor easy</td>
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<td>X</td>
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<td>Relatively easy</td>
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<td>X</td>
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<tr>
<td>Without any problems</td>
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<td></td>
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<td>X</td>
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</tbody>
</table>

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<tr>
<th>Reading (normal type, newspaper, book)</th>
<th>Test intervals (months of supervision)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3.25</th>
<th>5.75</th>
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<tr>
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<td>X</td>
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<tr>
<td>Partly possible</td>
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<td>X</td>
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<tr>
<td>Relatively easily possible</td>
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<td>Easily possible</td>
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<td>X</td>
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</table>

<table>
<thead>
<tr>
<th>Eye-hand-coordination (grasping)</th>
<th>Test intervals (months of supervision)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3.25</th>
<th>5.75</th>
<th>6.75</th>
</tr>
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<tbody>
<tr>
<td>Always missing the target</td>
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<tr>
<td>Sometimes missing the target</td>
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<td>X</td>
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<tr>
<td>Never missing the target</td>
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1996; Polat et al., 2004), our study documented for the first time various visual functions prospectively after loss of the non-amblyopic eye and intervention by psychophysical training. Of course, more experience is needed to determine the role of the intervention vs. spontaneous recovery (Fronius et al., 2005). For a comparison of the amount and speed of improvement, prospective documentation of cases with similar pathology in both the previously dominant and the amblyopic eye (strabismic vs. anisometropic amblyopia, central vs. eccentric fixation, unchanged or new optical correction) would be necessary. A patient with similar conditions to the one presented here did not show any improvement, neither spontaneously nor after administration of pleoptics or Levodopa (Schulz, 1998).

Unspecific learning and memory effects may also play a role, especially in the spatial localization tasks, where the patient might avoid positions where she had received negative feedback. However, improved grating resolution in forced-choice testing, enhanced contrast sensitivity, the sudden pointing shifts after pleoptics as well as the optotype acuity increase for untrained tests (Fronius et al., 2005) rather seem to indicate that the visual system is capable of changing. Although the training was time- and energy-consuming, the patient was satisfied about the improvement. Further experience may specify which procedures have the most impact and thus are most worth using in such desperate situations. Of course, detection and treatment of amblyopia in childhood remains the preferable way of avoiding them.

ACKNOWLEDGEMENTS

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REFERENCES