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Deleterious effects of roving on learned tasks

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ABSTRACT

In typical perceptual learning experiments, one stimulus type (e.g., a bisection stimulus offset either to the left or right) is presented per trial. In roving, two different stimulus types (e.g., a 30′ and a 20′ wide bisection stimulus) are randomly interleaved from trial to trial. Roving can impair both perceptual learning and task sensitivity. Here, we investigate the relationship between the two. Using a bisection task, we found no effect of roving before training. We next trained subjects and they improved. A roving condition applied after training impaired sensitivity.

1. Introduction

In classical psychophysical experiments, one out of two stimulus alternatives is randomly presented per trial. For example, in a bisection task, two parallel lines are presented along with a central line that is offset either to the left or to the right (Fig. 1A). Subjects indicate the offset direction. In roving, one out of four stimulus alternatives (or even more) from two stimulus types is presented per trial, e.g., bisection stimuli separated by either 20′ (arcminutes) or 30′ with left and right offsets (Fig. 1A and B).

Roving hinders perceptual learning (Adini et al., 2004; Kuai et al., 2005; Otto et al., 2006; Yu, Klein, & Levi, 2004; Zhang et al., 2008), unless observers undergo abundant training, on the range of 18,000 trials (Parkosadze et al., 2008). This is roughly an order of magnitude greater than the 1500 trials that are sufficient for learning under non-roving conditions (Aberg & Herzog, 2009; Otto et al., 2006; Parkosadze et al., 2008). For sufficiently different stimuli, e.g., vertical versus horizontal bisection stimuli, roving does not hinder perceptual learning (Tartaglia, Aberg, & Herzog, 2009).

In a recent study, observers with and without experience in music-reading judged whether a dot was on or off a line on a musical staff (Wong et al., submitted for publication). The staff lines could be either horizontal or vertical. Music readers outperformed non-readers for the conventional horizontal staff lines but not for vertical staff lines. Surprisingly, when vertical and horizontal staff lines were randomly interleaved from trial to trial (i.e., roving), experts were even worse than novices. It seems that roving affects perceptual learning *and*, in addition, sensitivity amongst experts, i.e., after a skill has been successfully learned.

Other studies, however, have found that expert sensitivity is unaffected by roving (Adini et al., 2004; Kuai et al., 2005; Nahum, Nelken, & Ahissar, 2012; Zhang et al., 2008). These studies used an assortment of tasks ranging from contrast increment detection (Kuai et al., 2005; Zhang et al., 2008) to auditory word discrimination (Nahum, Nelken, & Ahissar, 2012). Here, we investigated the effects of roving on pre- and post-training task sensitivity using bisection stimuli for which roving clearly affects learning.

2. General materials and methods

2.1. Observers

Observers included students, each of whom were from either the École Polytechnique Fédérale de Lausanne (EPFL) or from the University of Lausanne (UNIL), and who were naïve to the study's purpose. Ten observers participated in Experiment 1 and nine new observers in Experiment 2 (three females, mean age 22.81; and five females, mean age 23.6, respectively). Ten new observers participated in Experiment 3 (seven females, mean age 22.3) and another ten new observers participated in Experiment 4 (5 females, mean age 21.6). All observers had normal or corrected to normal acuity as assessed by the Freiburg visual acuity test (Bach, 1996). Observers were told that they could quit the

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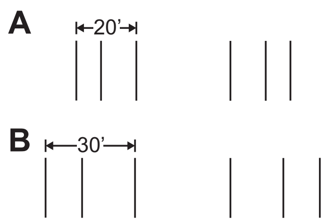

Fig. 1. (A) Per trial, a 20′ bisection stimulus had its center line offset either to the left or to the right. The distance between the outer lines is 20′. (B) A 30′ bisection stimulus. In roving, all four stimulus alternatives (A and B) were presented intermixed over trials.

experiment at any time they wanted and written informed consent was obtained. Observers were remunerated for participation (20 CHF per hour). All procedures conformed to the declaration of Helsinki.

2.2. Apparatus

Stimuli appeared on the center of either a Tektronix 608 display or a Hewlett Packard 1332A X-Y display, controlled by a PC via a 16-bit digital-to-analog converter (1 MHz pixel rate). Each observer was consistently tested with the same set-up at the EPFL. Line elements were composed of dots with a 200 µm pitch. The dot pitch was selected to make the dots slightly overlap, i.e. the dot size (or line width) was of the same magnitude as the dot pitch. Stimuli were refreshed at 200 Hz. Luminance was 80 cd/m^2, as measured with a two-dimensional dot grid using the aforementioned dot pitch and refresh rate and a Minolta LS-100 luminance meter equipped with a close-up lens (Minolta No. 122). The room was dimly illuminated (0.5 lux) and background luminance on the screen was below 1 cd/m^2. The viewing distance was 2 m.

2.3. Statistics

We measured sensitivity (d') as a function of training during the training sessions (Fig. 3A). To account for the different observers' improvement rates, we weighted our t-tests by learning strength, measured by the subjects' average improvement from the first four training blocks to the last four training blocks:

$$w_i = \frac{\overline{\text{last four}_i} - \overline{\text{first four}_i}}{\sum_{j=1}^{n} \overline{\text{last four}_j} - \overline{\text{first four}_j}} \quad (1)$$

$$D_i = w_i \cdot (\overline{\text{roving}_i} - \overline{\text{last four}_i}) \quad (2)$$

$$t = \frac{\overline{D}}{\sigma_D} \quad (3)$$

Here i and j index the observers, n is the total number of observers, $\bar{\bullet}$ denotes the mean and σ_D is the standard error on the difference scores. Under this formulation, in the case where subjects did not improve from their first four learning blocks to their last four, their weight w_i would be zero and their difference score would not count towards the resulting t-value. For the subject who improved the most from the first four training blocks to the last four training blocks, their weight would be the highest and their difference score would contribute the most to the resulting t-value. In this way, the t-statistic is un-biased by results from subjects who failed to learn the task, and for the remaining subjects, their contribution is weighted by how much they learned.

To investigate the influence of roving *after* training, in experiments 2, 3, and 4 we took the average sensitivity of all four roving blocks and subtracted the average sensitivity of the last four training blocks.

3. Experiment 1

In Parkosadze et al. (2008) it was shown that roving with bisection stimuli prior to learning does not affect bisection thresholds. Here, we replicated this effect with a slightly different procedure, showing that roving does not affect bisection *sensitivity* prior to learning.

3.1. Stimuli and task

Observers discriminated the offset of a central line (left or right) in a bisection stimulus. Bisection stimuli were 20′ (arcminutes) tall (Fig. 1).

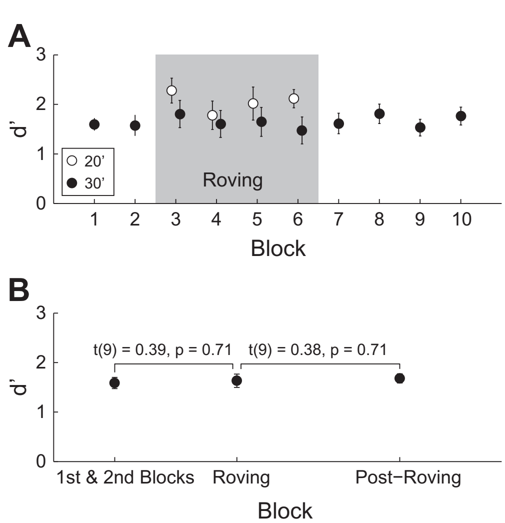

Fig. 2. Results for Experiment 1. (A) Black-filled symbols plot data for the 30′ bisection stimulus and white-filled symbols plot data for the 20′ bisection stimulus. The gray regions denote the roving blocks while the white regions are non-roving blocks. (B) Mean sensitivity averaged over the first two baseline blocks, the four roving blocks, and the four post-roving blocks for the 30′ bisection stimulus. Symbols as in A. Error bars plot ±1 SEM.

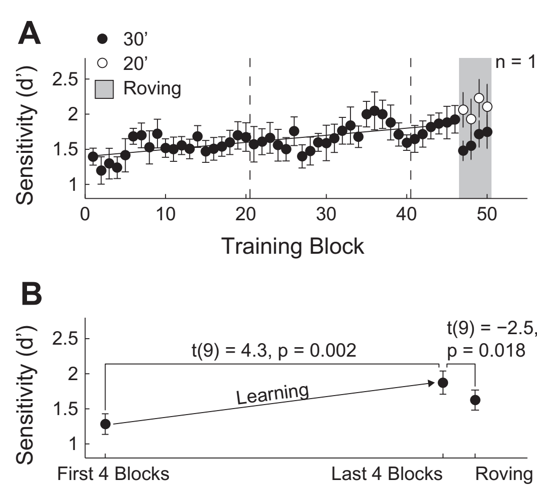

Fig. 3. Experiment 2. (A) Mean sensitivity (d') for eight observers. Black-filled symbols plot data for the 30′ bisection stimulus and white-filled symbols plot data for the 20′ bisection stimulus. The vertical dashed lines mark the different days. The gray shaded region marks the roving blocks. Performance improves from block 1 to block 46 with the 30′ bisection stimulus. When in addition the 20′ bisection stimuli are presented (roving) performance deteriorates for the 30′ bisection stimulus. (B) Mean sensitivity averaged over the first four training blocks, the last four training blocks and the four roving blocks for the 30′ bisection stimulus. Training led to a significant improvement. This improvement was diminished by post-training roving. Symbols as in A. Error bars plot ±1 SEM.