PROBING SENSORY ATTENUATION FOR SELF-INITIATED ACTIONS USING VIRTUAL REALITY

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INTRODUCTION

Self-generated outcome is perceived as less intense than the same sensory input generated externally. This phenomenon, called Sensory Attenuation (SA), is often explained by motor-based forward models. Recent developments in the research of SA, however, challenge these models. While motor-based forward models of SA imply that predictions are mainly based on efference copies of motor commands, predictive processing implies attenuation of all anticipated sensory stimuli, independent of whether a self-initiated motor response was the perceived cause. Using Virtual Reality in an adapted study design (Vasser et al., 2019), we aimed to examine the abilities of motor-based forward models and predictive processing in explaining SA. We hypothesized to replicate the findings of Vasser et al. (2019), demonstrating significant differences in contrast perception for different conditions - with SA effects visible if the participants' virtually invisible hands were moved into the same visual field as the stimuli. Further, according to the predictive processing model, we hypothesized to find no SA effects in trials with a varying delay between hand movement and stimulus onset - highlighting the effects of temporal predictability as a predictor (Kaiser & Schütz-Bosbach, 2018; Harrison et al, 2021). The static condition (i.e., without hand movements) examined SA effects in spite of self-initiated motor behavior. In line with the predictive processing model, we hypothesized to find a weakening of SA effects (Dogge et al., 2019).

METHODS

We recruited 33 healthy participants with normal or corrected-to-normal vision. 3 participants were excluded due to not showing an increase in higher contrast judgements between the two lower test contrast values and the two higher test contrast values.

In a two-alternative forced choice task, participants compared the intensity of two Gabor contrasts (0.2, 0.25, 0.3, 0.36, 0.45; for 133ms); one behind participants' virtually invisible moving hand and one not. In four different blocks, stimuli either appeared immediately after motor-behavior (Immediate), with a varying delay (Delay; 700ms, 750ms and 800ms), independent of the participants' actions (Static) or with both Gabor contrasts outside of the visual field covered by the virtually invisible hand (Control) (Figure 1). Each block consisted of 300 trials (150 trials per hand).

RESULTS

A within-subjects ANOVA showed a main effect of contrast [$F(2.11, 59.08) = 197.43$, $p < 0.001$, $\eta^2_G = 0.80$], but no main effect for condition [$F(2.93, 82.06) = 0.53$, $p = 0.62$, $\eta^2_G = 0.005$]. However, we found an interaction effect between condition and contrast [$F(5.99, 167.67) = 2.20$, $p < 0.044$, $\eta^2_G = 0.036$] (Figure 2). Further, we assessed differences in contrast perception by analyzing variations of the point of subjective equality (PSE) depending on the different conditions (Figure 3). Post-hoc pairwise comparisons of PSE values per condition for each test contrast showed significant differences between the immediate and control condition, and the static and control condition from test contrasts as off 0.36 [Immediate: $t(57) = 2.42$, $p = 0.026$; Static: $t(57) = 2.21$, $p = 0.032$] (Figure 4).

DISCUSSION

The findings of Vasser et al. (2019), hence the reduction of the apparent stimulus contrast through self-initiated movement, could only be reproduced for stronger contrasts (0.36, 0.4, 0.45). This is in line with several research suggesting that the perceived intensity of self-initiated stimuli is modified by their strength (Reznik et al., 2015). Further, we could extend the findings reported by Vasser et al. (2019). We have found no effects of SA in trials with a varying delay between hand movement and stimulus onset, highlighting the importance of temporal predictability as a predictive mechanism. Further, significant differences in mean higher contrast responses were found between the static and control condition (for contrasts as off 0.36), underlining the influence of self-initiated motor behavior as a reliable predictor for SA.

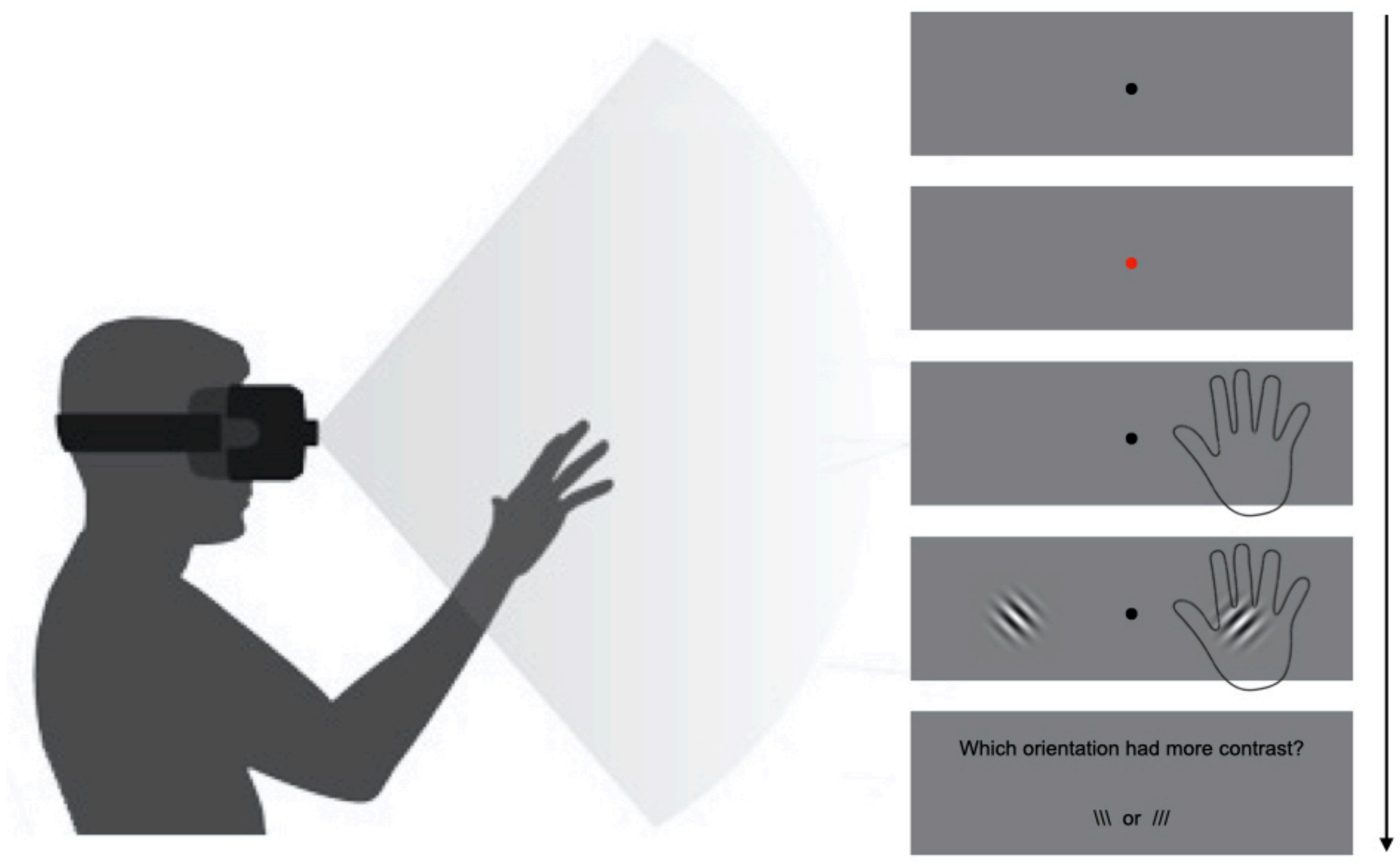

Figure 1: Experimental Setup.
Study design adapted from Vasser et al. (2019). Gabor contrast pairs varied in contrast, spatial frequency, and orientation. The black dot in the middle is the gaze fixation point.

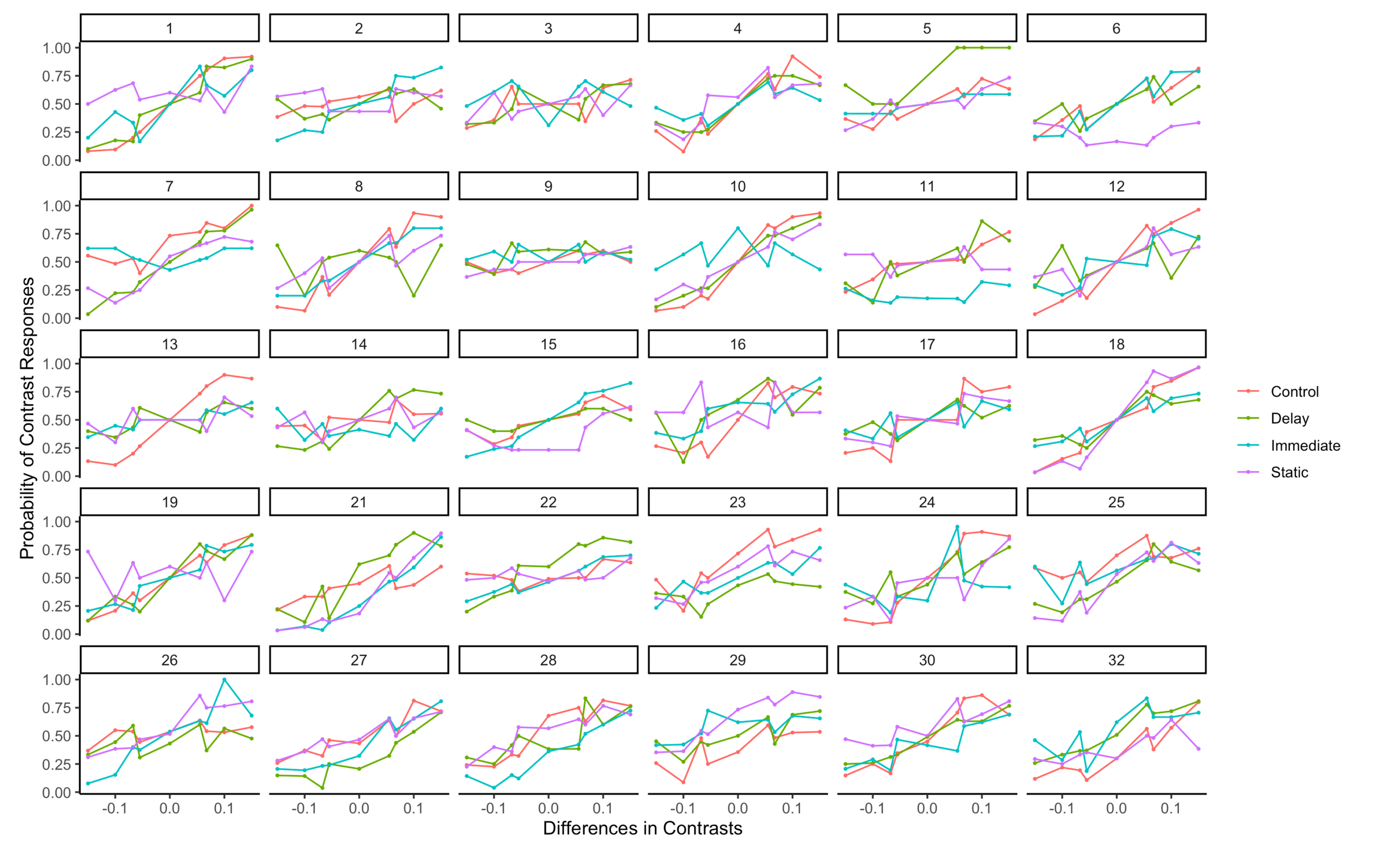

Figure 2: Individual contrast response values per test contrast for each condition.
Line Graph distribution showing the probability of higher contrast responses for each test contrast and condition for each subject.

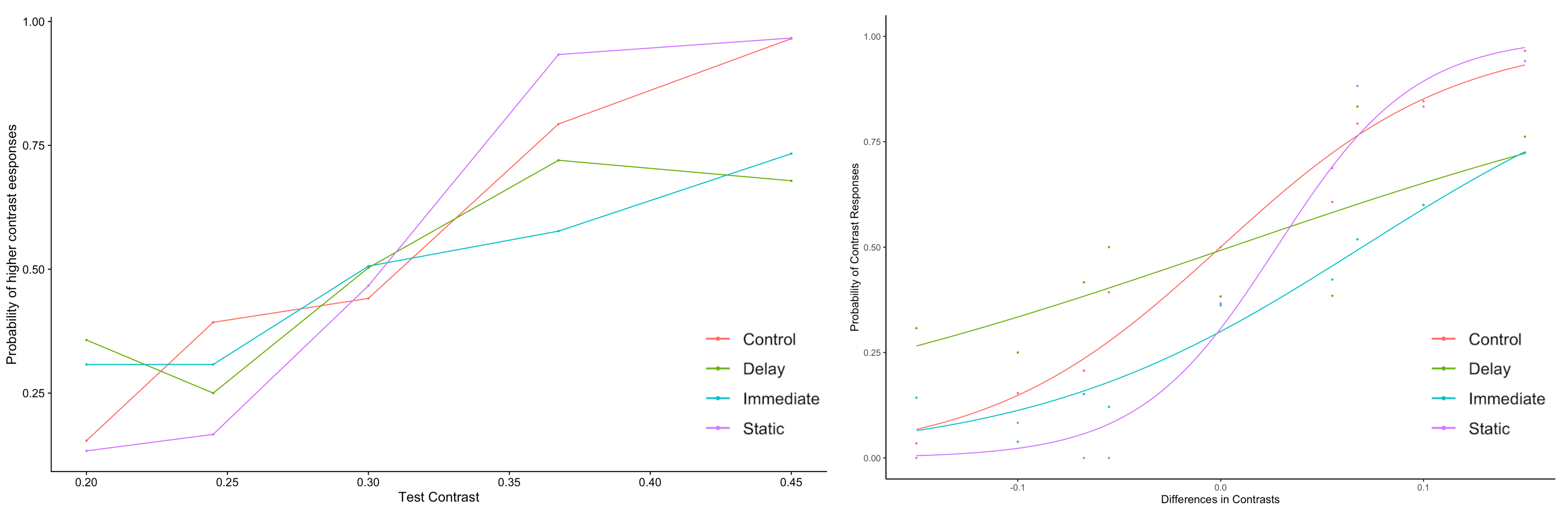

Figure 3: Point of Subjective Equality Analysis using the psychometric function.
Example of a psychometric fit for contrast responses, used of PSE analysis.

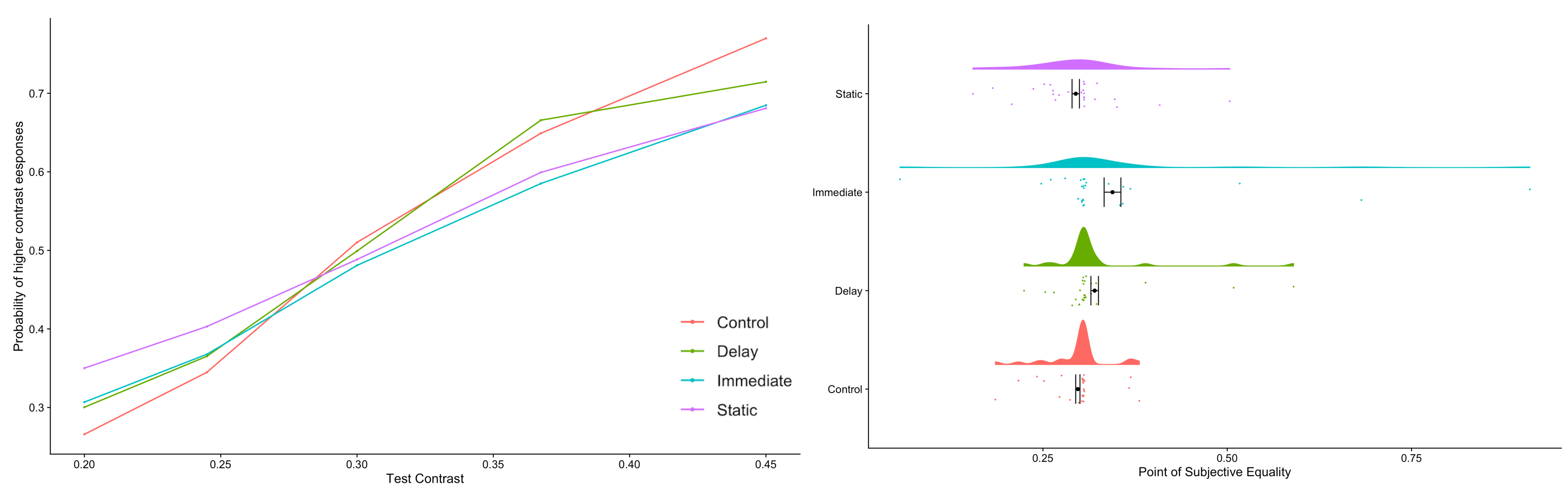

Figure 4: Comparing mean contrast response values per test contrast for each condition. Line Graph distribution showing the mean probability of higher contrast responses for each test contrast and condition.

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