Decreased visual detection during subliminal stimulation

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What is the perceptual fate of invisible stimuli—are they processed at all and does their processing have consequences for the perception of other stimuli? As has been shown previously in the somatosensory system, even stimuli that are too weak to be consciously detected can influence our perception: Subliminal stimulation impairs perception of near-threshold stimuli and causes a functional deactivation in the somatosensory cortex. In a recent study, we showed that subliminal visual stimuli lead to similar responses, indicated by an increase in alpha-band power as measured with electroencephalography (EEG). In the current study, we investigated whether a behavioral inhibitory mechanism also exists within the visual system. We tested the detection of peripheral visual target stimuli under three different conditions: Target stimuli were presented alone or embedded in a concurrent train of subliminal stimuli either at the same location as the target or in the opposite hemifield. Subliminal stimuli were invisible due to their low contrast, not due to a masking procedure. We demonstrate that target detection was impaired by the subliminal stimuli, but only when they were presented at the same location as the target. This finding indicates that subliminal, low-intensity stimuli induce a similar inhibitory effect in the visual system as has been observed in the somatosensory system. In line with previous reports, we propose that the function underlying this effect is the inhibition of spurious noise by the visual system.

An important goal of the study of perception is to understand how nonconscious stimuli affect perception and behavior. Numerous studies have addressed this question by rendering visual stimuli unconscious with masking techniques (Kouider & Dehaene, 2007). Notably, stimuli that are made invisible by masking are usually strong enough to be consciously perceived when presented without a mask. For such stimuli, studies have demonstrated effects of unconscious stimulus processing and effects on behavior and neuronal responses (Harris, Wu, & Woldorff, 2011; Haynes & Rees, 2005). However, a stimulus may remain unconscious not due to a mask but rather due to its low intensity or contrast. It is currently unknown whether the visual system responds in a similar fashion to stimuli that are invisible due to their low contrast.

For the somatosensory system, Blankenburg et al. (2003) demonstrated perceptual changes due to stimuli that are undetectable because of their subthreshold intensity. Using functional magnetic resonance imaging (fMRI) during subliminal stimulation of the right index finger, the authors found blood oxygenation level-dependent (BOLD) signal decreases in corresponding somatosensory cortical areas, which stands in contrast to BOLD signal increases that are usually observed for supraliminal finger stimulation. In a subsequent psychophysical experiment, detectability of somatosensory near-threshold targets was decreased during concurrent subliminal stimulation.
subliminal stimulation. In accordance with the behavioral results, the BOLD signal decrease in response to subliminal stimuli was interpreted as a focal inhibition mechanism that protects the cortex against spurious activation by noise.

In a recent study, we showed that subliminal visual stimuli led to an equivalent inhibitory response within the visual system, indicated by an increase of alpha-band power. In contrast, supraliminal stimuli evoked a lower-frequency increase as well as a decrease in alpha-band power. In accordance with the previous literature, we interpreted this response as an inhibitory mechanism, which reduces spurious activation that is unlikely to result from external stimuli (Bareither, Chaumon, Bernasconi, Villringer, & Busch, 2014).

In the current study, we investigated whether perceptual consequences of such an inhibitory mechanism can be found within the visual system as well. We studied psychometric functions in a target detection task when those targets either were presented alone or were embedded in a concurrent train of subliminal stimuli at the same location as the target stimulus or in the hemifield opposite to the target stimulus. Compared with target stimuli presented alone, we found significantly elevated detection thresholds for target stimuli during subliminal stimulation on the same side. No effect was found for target stimuli presented with the subliminal stimulus train on the opposite side. This result shows for the first time that subliminal visual stimuli that are not detectable due to their low contrast can influence visual perception by inhibiting the detection of periliminal stimuli.

The following methods are similar to those of Bareither et al. (2014).

**Methods**

**Participants**

Seven participants (aged 20–27 years, mean age 22.7 years; six females, six right-handed) took part in this experiment. Three participants completed one session and four participated in up to five sessions, resulting in 19 sessions total. A single session of the study consisted of Phase I (180 trials) followed directly by Phase II (1,260 trials). Participants always took part in both phases during one session. None of the participants reported a history of neurological or psychiatric disorders and all had normal or corrected-to-normal vision. Informed consent was obtained from each participant after explanation of the study. The experiment was approved by the Ethics Committee of the Charité-Universitätsmedizin Berlin, according to the Declaration of Helsinki.

**Stimulus and apparatus**

The experiment was programmed in Matlab (Mathworks, Inc., Natick, MA) using the Psychophysics Toolbox (Brainard, 1997). Participants were seated in a dark, sound-attenuated chamber. Stimuli were presented on a gamma-linearized 19-in. Cathode ray tube (CRT) monitor (Samsung Syncmaster, Suwong, Korea) with 1280 × 1024 pixel resolution and a refresh rate of 100 Hz, located 56 cm from the participants’ eyes. Head position was stabilized using a chin rest. For all phases of the experiment, the background consisted of a spatially modulated, random white noise pattern. Mean luminance of the background pattern was 10.76 cd/m². A central red fixation cross 0.63° in diameter was continuously present on the screen. The target stimulus was an unfilled circle (ring), 0.76° in diameter (inside diameter 0.39°), presented once for 30 ms. The stimulus train consisted of seven consecutive filled circular patches, each 0.38° in diameter. The patches were presented at a 7-Hz rate for 870 ms. Each of the seven patches was presented for 30 ms with a prestimulus interval of 110 ms. Both target stimuli and train stimuli were presented on the horizontal meridian at an eccentricity of 18.3° to the right or the left of the fixation cross. Participants were instructed to always maintain central fixation. In one session of the experiment, participants were tested in Phase I (threshold estimation) followed directly by Phase II (experimental test).

**Procedure**

**Phase I: Contrast threshold estimation**

Stimulus contrasts were determined individually for each participant to account for interindividual differences in sensitivity. In the first phase of the experiment, we estimated each participant’s absolute sensitivity threshold for the stimulus train as well as the 50% performance threshold for the target stimulus. This was done in order to find individual thresholds that could be used in Phase II of the experiment, which immediately followed Phase I. Finding the absolute threshold for train stimuli was important to create a stimulus that was invisible for each individual on every trial. The purpose of the 50% detection threshold for target stimuli was to ascertain the level of contrast that could serve as the individual midpoint of the full psychometric function, which encompasses stimulus contrast ranging from virtually invisible to clearly visible.

Each trial was initiated via button press and started with the presentation of a fixation cross, which was from then on presented continuously on the screen for the whole trial. After a variable delay (range: 1–1.5 s), stimuli were presented in 87.5% of the trials for each stimulus condition (train or target). The remaining trials
were stimulus-absent “catch” trials to estimate the false-alarm rate of each participant. After another delay of 1 s, the fixation cross turned into a question mark. With the presentation of the question mark, participants were asked to indicate via button press whether or not they saw any stimulus, be it a target stimulus or a stimulus train. Stimulus train and target stimuli never occurred on the same trial in Phase I, and the order in which train and target trials were presented was random. On each trial, the intensity of the train or target stimulus was chosen at random from the following set of seven intensities: stimulus train, 11.5, 12.0, 12.5, 13.0, 13.5, 14.5, and 15.0 cd/m², and target stimuli, 11.0, 12.3, 12.8, 13.0, 13.2, 14.5, and 15.5 cd/m², with 20 repetitions per intensity (and 20 repetitions for “catch trials”). The intensities were based on pilot experiments.

**Phase II: Target stimulus detection task**

In Phase II, we tested performance in a target detection task for target stimuli presented alone (No-train condition), target stimuli embedded in a stimulus train on the same side (Same-side condition), and target stimuli presented on the opposite side of the stimulus train (Opposite-side condition).

To ensure that the stimulus train was really subliminal, the contrast of the stimulus train (as estimated individually in Phase I) was set to 25% of the participant’s absolute sensitivity threshold. The target stimuli were presented in six different intensities distributed around the 50% threshold (0, 0.8, 1.2, 1.6, 3, and 5 times the threshold as calculated in Phase I), with 70 repetitions per intensity.

As in Phase I, trials were initiated via button press and started with the presentation of a fixation cross, which was from then on presented continually on the screen. After a variable delay (500–1100 ms), the stimulus train (if applicable; see below) and the target stimulus (if applicable; see below) were presented during an interval of 870 ms. After another delay of 520 ms (during which only the fixation cross was presented), the fixation cross turned into a question mark, and participants reported whether or not they detected a target stimulus (detection of trains was not required in Phase II).

The stimulus train was presented on two-thirds of the trials, either on the same side as the target stimulus (Same-side condition) or on the opposite side of the target stimulus (Opposite-side condition). For example, if the subliminal stimulus train was presented on the left, the target stimulus would be presented on the left as well (Same-side condition) or on the right (Opposite-side condition). The location of the subliminal stimulus train was chosen randomly. On the remaining one-third of trials, only target stimuli were presented (No-train condition), but the background was displayed for the same duration as in the other conditions such that trial durations were identical in all conditions (see Figure 1).

Following the third patch of the stimulus train, we interleaved the target stimulus after a delay of 30 ms, similarly to Blankenburg et al. (2003). The target stimulus was presented on 83.33% of the trials. The rest of the trials were stimulus-absent trials used to estimate the false-alarm rate.

The stream of 1,260 trials in total was interrupted by five breaks, separating the experiment into six blocks. Participants could start the next block manually.

**Data analysis**

In Phase I of the experiment, we estimated thresholds for the stimulus train as well as the target stimulus separately. To determine individual absolute sensitivity thresholds for the stimulus train, we calculated the D-prime (d’) of each of the different stimulus intensities using the participant’s hit rate for that intensity and the false-alarm rate. We then simulated the performance of
an observer with zero sensitivity in a detection task with the same number of signal trials and catch trials as in the real experiment. This simulation was repeated 100,000 times, yielding a distribution of expected $d\prime$ values for an observer with zero sensitivity. This allowed us to compute for each stimulus intensity whether a participant’s $d\prime$ was significantly greater than expected from blind guessing.

A participant’s absolute sensitivity threshold for train stimuli was defined as the minimal stimulus intensity required for a $d\prime$ for which this probability was less than 0.01. To determine the 50% threshold for target stimuli (i.e., the contrast required for 50% correct performance), we fitted the data (number of yes responses for each stimulus intensity) with a Weibull function, using the Palamedes Toolbox for Matlab (Prins & Kingdom, 2009). Psychometric functions were fitted by estimating the parameters $\alpha$ (threshold), $\beta$ (the slope), $\gamma$ (the guess rate), and $\lambda$ (the lapse rate). In this part of the experiment, initial guesses of Weibull function parameters $\gamma$ (the guess rate) and $\lambda$ (the lapse rate) were given according to individual responses.

As in Phase I, the 50% threshold for target detection in Phase II was determined by fitting a Weibull function through the averaged data for each of the three conditions (No-train, Same-side, and Opposite-side) using the Palamedes Toolbox for Matlab. In Phase II, initial guesses of Weibull function parameters ($\alpha = 1$, $\beta = 3$, $\gamma = 0.01$, $\lambda = 0.01$) were the same for all participants. Parameters were free to vary, with the constraint that lapse rate and guess rate varied between 0 and 0.1.

In order to analyze differences for the resulting 50% thresholds between conditions, we conducted a repeated-measures analysis of variance (ANOVA) with condition (No-train, Same-side, Opposite-side) as the within-subject variable.

## Results

### Phase I

We estimated each participant’s absolute threshold for the stimulus train as well as the 50% detection threshold for the target stimulus in Phase I of the experiment. The mean over all participants tested in Phase I for the absolute threshold for train stimuli was 0.1688 ($SD = 0.0051$), corresponding to a luminance of 12.2 cd/m². The mean of the 50% detection threshold for target stimuli was 0.1764 ($SD = 0.0042$), corresponding to 12.8 cd/m².

Individual absolute thresholds for the stimulus train were used in Phase II of the experiment. To ensure the subliminal nature of the stimulus train, their luminance was set to 25% of the absolute threshold as estimated in Phase I.

### Phase II

A repeated-measures ANOVA tested the 50% thresholds of the psychometric functions obtained in the target detection task for differences between the...
The findings are robust (i.e., the main findings did not perform the analysis with and without this subject. We unexpectedly high detection rate of this subject, we performed the analysis with and without this subject. The findings are robust (i.e., the main findings did not change whether the subject was included or excluded in the analysis).1

Table 1. Thresholds of individual participants for the three conditions (No-train, Same-side, and Opposite-side). Subtraction of the Same-side condition from the No-train condition results in negative and positive numbers around zero, indicating no effect of subliminal stimuli presented in the opposite hemifield. Subtraction of the Same-side condition from the Opposite-side condition shows that only the data points of participant 2 are nearly overlapping. Same = Same-side condition; Opposite = Opposite-side condition.

<table>
<thead>
<tr>
<th>Individual</th>
<th>No-train</th>
<th>Same</th>
<th>Opposite</th>
<th>Same – No-train</th>
<th>Opposite – No-train</th>
<th>Same – Opposite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.44</td>
<td>1.48</td>
<td>1.41</td>
<td>0.04</td>
<td>−0.03</td>
<td>0.07</td>
</tr>
<tr>
<td>2</td>
<td>1.33</td>
<td>1.36</td>
<td>1.35</td>
<td>0.03</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>3</td>
<td>1.23</td>
<td>1.32</td>
<td>1.24</td>
<td>0.09</td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td>4</td>
<td>1.21</td>
<td>1.24</td>
<td>1.19</td>
<td>0.03</td>
<td>−0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>5</td>
<td>1.21</td>
<td>1.28</td>
<td>1.23</td>
<td>0.07</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>6</td>
<td>1.03</td>
<td>1.16</td>
<td>1.03</td>
<td>0.13</td>
<td>0.00</td>
<td>0.13</td>
</tr>
<tr>
<td>7</td>
<td>0.66</td>
<td>0.81</td>
<td>0.77</td>
<td>0.15</td>
<td>0.11</td>
<td>0.04</td>
</tr>
</tbody>
</table>

In this study, we investigated whether the presentation of subliminal stimuli can influence the perception of perliminal visual target stimuli. When compared with a condition in which peripheral targets were presented alone, concurrent subliminal stimulation at the same location as the target resulted in a significantly increased detection threshold. Subliminal stimulation in the opposite hemifield did not lead to any significant changes in thresholds. These results were confirmed for each of the individual participants as shown in Figure 2B.

It is important to point out the nature of the subliminal stimuli used in this experiment. Unlike in many other studies in which a visible stimulus is made invisible by masking, the subliminal stimuli used in the present experiment were of such low contrast that they could not be detected without any interference of an additional mask stimulus. As a consequence, the presence of the stimulus itself was imperceptible. This stands in contrast to a number of studies that have investigated the effect of invisible stimulus features. For example, it has been found that stimuli flickering so fast that the flicker is not perceived can induce flicker adaptation (Shady, MacLeod, & Fisher, 2004). Moreover, unresolvable Gabor patches with spatial frequencies beyond the resolution limit can induce adaptation and a tilt aftereffect (He & MacLeod, 2001; Rajimehr, 2004). However, it is important to point out that all of these stimuli are subliminal only in the sense that their specific features (flicker, orientation) are not visible, while their presence clearly is. Thus, the strength of these stimuli makes them clearly distinguishable from noise within the
visual system. We propose that the inhibitory effect of imperceptible low-contrast stimuli, as used in the present study, results from a filter mechanism that discards signals that are too weak to be likely resulting from a real input signal.

Furthermore, several studies have demonstrated that repeated exposure to task-irrelevant subliminal stimuli (e.g., subthreshold contour or motion stimuli) can induce unconscious perceptual learning (Rosenthal & Humphreys, 2010; Tsushima, Seitz, & Watanabe, 2008; Watanabe, Nanez, & Sasaki, 2001). For example, repeated exposure to a specific motion direction, while observers perform an unrelated task, improves sensitivity for this motion direction when motion discrimination is tested in a subsequent test phase (Tsushima et al., 2008). In contrast to subliminal perceptual learning, the effect found in the present study reduced sensitivity for detection of target stimuli that did not share a specific feature with the subliminal train.

Similarly, presenting a subthreshold background or “pedestal” stimulus simultaneously together with a superimposed target stimulus increases the target’s detectability (Bird, Henning, & Wichmann, 2002; Kachinsky, Smith, & Pokorny, 2003; Kontsevich & Tyler, 1999). In contrast to the “pedestal effect,” here we show that subliminal stimuli that are presented spatially nonoverlapping and asynchronous to the target stimulus do not increase but rather decrease the target’s detectability.

We ensured that subliminal stimuli were truly invisible by measuring participants’ sensitivity using $d’$ as a performance measure (Phase I), which is independent of response bias (Green & Swets, 1966). We determined each participant’s absolute threshold by finding the train stimulus intensity at which $d’$ was not significantly different from the simulated $d’$ of a model observer with zero sensitivity. Furthermore, to ensure that subliminal stimuli were below the visibility threshold, subliminal train stimuli in Phase II were presented at only 25% of this absolute threshold. Thus, it is reasonable to assume that in Phase II, subliminal stimuli remained invisible and that only target stimuli were consciously perceived. In fact, none of the participants reported ever seeing a stimulus train in Phase II.

How did the trains of invisible stimuli come to impair the detection of the target stimuli? The effects shown in this experiment resemble effects resulting from metacontrast masking experiments. On the most general level, masking can be regarded as the decreased visibility of an object (the target) through another object (the mask). In our experiment, the outer ring would specify the target, while the inner patch following the ring would specify the mask. Indeed, the stimulus-onset asynchrony (SOA) between target and mask (80 ms) would entail a favorable SOA for metacontrast masking.

In masking experiments, the target stimulus is usually surrounded by a mask that is at least comparable in physical strength or mask energy (duration and intensity; Breitmeyer & Ogmen, 2006). Interestingly, in this experiment, a low-contrast subliminal stimulus would mask a target stimulus that is higher in contrast as well as bigger in size, further increasing its physical strength or mask energy. Could theories on visual masking explain why the visibility of perliminal targets was reduced by subliminal stimulus trains?

In current models of visual processing, awareness is achieved by feedforward and feedback processes within lower-level and higher-level visual areas. Awareness is thereby characterized through a sustained and stable neural activation pattern, dependent on physical stimulus strength (in terms of duration or intensity; Kiefer et al., 2011). This neural activation pattern of a target is assumed to be disturbed in masking experiments. That is, masking is assumed to occur through the disturbance of feedback mechanisms (e.g., close temporal succession of a second stimulus) that masks the neural representation of the first stimulus and thereby leads to a mismatch between neural activation patterns (Enns & DiLollo, 2000; Kiefer et al., 2011; Lamme & Roelfsema, 2000). If the neural representation is dependent on physical stimulus strength, it is not surprising that masking experiments systematically varying mask–target energy ratio show that the physical strength (intensity) of the mask in relation to the target is directly related to the metacontrast masking effect (Alpern, 1953). In these early studies, the magnitude of the metacontrast effect increased with increased intensity of the mask or decreased intensity of the target.

Based on these studies, a masking effect due to a subliminal mask that is surrounded by the target (further decreasing its physical strength in comparison with the target) would be expected to be small, if at all present. By contrast, the effect size found in our study indicates a strong effect ($\eta^2_p = 0.67$).

Further, it is also unlikely that subliminal stimuli, despite being invisible, could have acted as temporal or spatial attentional cues, such that target detection was affected by attention. Spatial attentional cueing should have resulted in improved performance for targets presented at the cued location and impaired performance for targets presented at the noncued location in the opposite hemifield, as compared with targets presented alone. Temporal cueing would have improved target detection regardless of the spatial locations of subliminal train and target. However, detection performance was in fact impaired for targets presented at the same location as the subliminal...
stimulus train and unchanged for targets presented at the opposite side, indicating that subliminal trains did not act as attentional cues.

Our results are in line with a study by Blankenburg et al. (2003), who demonstrated reduced detectability of near-threshold somatosensory stimuli with concurrent subliminal finger stimulation. In an experiment using fMRI, the authors found decreased BOLD activation in corresponding somatosensory cortices. Furthermore, it was demonstrated that the detectability of finger stimulation is reduced by subliminal somatosensory stimulation of an adjacent finger (Taskin, Holtze, Krause, & Villringer, 2008). This behavioral outcome was in line with the finding of an fMRI experiment showing that subliminal stimulation of an adjacent finger reduced the BOLD signal response to the target finger in the contralateral primary somatosensory cortex (SI). The authors propose that the effect is due to considerable overlap of adjacent fingers in SI. Blankenburg et al. (2003) and Taskin et al. (2008) proposed that this effect is due to an inhibitory response to low-intensity somatosensory stimuli that protects the cortex from spurious channel noise.

We have previously shown a similar cortical response within the visual system. We presented subliminal and supraliminal visual stimuli after estimating each participant’s detection threshold similarly to Phase I in the current study. Stimuli consisted of single filled, circular patches. Subliminal and supraliminal stimuli elicited different neuronal response patterns. Supraliminal stimuli led to the well-known response of an early increase in lower frequencies as well as a decrease within the alpha band and higher frequencies after 400 ms (event-related desynchronization). By contrast, subliminal stimuli elicited an alpha-band power increase around 300 ms. We suggest in accordance with findings in the somatosensory system that the alpha rhythm increase may be due to a mechanism that usually inhibits noise (Bareither et al., 2014).

This inhibitory mechanism could be mediated by inhibitory interneurons. Inhibitory cortical interneurons in SI as well as the primary visual cortex (V1) have lower stimulation thresholds compared with excitatory neurons (Swadlow, 2003; Zhuang et al., 2013). Subliminal sensory stimulation might therefore lead to a favored activation of feedforward inhibitory interneurons. Generally, inhibitory neurons in SI and V1 seem to exhibit comparable properties (Swadlow, 2003; Zhuang et al., 2013). For example, in both rabbit and rat, suspected inhibitory interneurons in V1 and SI are highly excitable but low in their specificity and exhibit short latencies to peripheral stimulation. It is therefore not surprising that the period of inhibition seems to be similar for somatosensory and visual stimuli—namely, within 30 ms. However, the specifics of this timing are very much dependent on the specifics of the stimuli presented as well as response latencies of subliminal and supraliminal stimuli. Other methods, such as single-cell recordings, would be necessary to investigate the timing of the inhibition involved here. The goal of the present study was to replicate the findings within the somatosensory system. Future studies will have to investigate responses to different SOAs.

We propose that a similar inhibitory mechanism is responsible for the deleterious effect of subliminal visual stimuli on the detection of perliminal targets in the somatosensory system as well as the visual system. Whereas current theories of masking assume a mismatch between feedforward and recurrent processes, in our framework, decreased perception of the perliminal target stimuli occurs through the activation of inhibitory interneurons that are preferentially activated through the subliminal stimulus. This activation of inhibitory interneurons leads to an unspecialized downregulation of noise that inhibits the perliminal target stimulus presented concurrently at the same retinal location.

As in the somatosensory system, the function of such a mechanism could be a protection of the cortex against unwanted noise—stimuli that are too weak to be real or of any relevance. Such a protection mechanism would be similar to inference mechanisms that are abundant in visual processing; for example, in the computation of object shape, texture, distance, or color (Rock, 1983). Prior to inferences about the features of a visual event, the visual system needs to decide based on visual input whether any visual event has occurred at all or whether an excitation is simply due to noise. One instance of such an inhibitory inference mechanism is the perceptual scotoma account of motion-induced blindness (New & Scholl, 2008), in which target objects in full view fluctuate into and out of awareness when superimposed onto a global moving pattern (Bonneh, Cooperman, & Sagi, 2001; Wu, Busch, Fabre-Thorpe, & VanRullen, 2009). According to the perceptual scotoma account, the visual system filters out input signals that are more likely due to imperfections of the eyeball or retina than to real events in the world. Thus, when visual input indicates a small object that is invariant with respect to salient, global stimulus changes, the visual system makes the inference that this input is unlikely to result from a real object, to the effect that processing of the target is inhibited and the target object is not consciously perceived. Likewise, in the case of very weak subliminal stimuli, the visual system might also infer that the input signal is not of sufficient strength to indicate a real visual stimulus and momentarily inhibit further processing, including the processing of other stimuli at the same location.
Conclusions

We present the first evidence for an inhibitory effect of low-contrast subliminal stimuli on visual detection. We suggest that stimuli escaping conscious perception—and periliminal stimuli presented concurrently at the same location—may be subject to an inhibitory mechanism, which normally inhibits visual noise.

Keywords: subliminal, low contrast, inhibition, inhibitory interneurons, masking, subthreshold

Acknowledgments

This work was supported by the Max-Planck Institute for Demographic Research, Rostock and by the German Research Foundation (DFG) under the research network “Neuro-cognitive mechanisms of conscious and unconscious visual perception” [Grant# BU2400/1-1].

Commercial relationships: none.
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Footnote

1Results of the ANOVA excluding the participant with the lowest threshold showed significantly different thresholds for all three conditions, $F(2, 10) = 14.067, p < 0.001, \eta_p^2 = 0.74$. Pairwise comparisons showed significantly different thresholds for the No-train versus the Same-side condition, $t(5) = -4.12, p < 0.01$, and the Same-side versus the Opposite-side condition, $t(5) = 4.1, p < 0.01$. No significant thresholds were found for pairwise comparison between the No-train and Opposite-side conditions, $t(5) = -0.085, p = 0.9$. This result shows that the main results were not driven by this participant.

References


