Visual processing out of awareness

When does subliminal information have an influence on the global effect?

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Abstract

The current experiment was designed to find a possible common denominator between the target and distractor that causes a subliminal influence on behavior. The color of a stimulus was suppressed by visual backward masking to find out what influence it would have on the global effect compared to other conditions, such as different suppressed colors or supraliminal conditions. Observers were told to make fast eye-movements to a stimulus target to be assured of a global effect in the baseline condition. The subliminal conditions did have a specific influence on the saccades; they decreased saccade latency and increased the global effect. The observers did not process the surface color of the subliminal stimulus as no significant difference between subliminal conditions has been found in this study.

Introduction

When an observer is instructed to make a saccade towards a target, and a distractor[1] with similar features is nearby (e.g. two circles of slightly different colors), the end-point of that movement will often be positioned in between the two stimuli. This phenomenon is called saccadic averaging or the global effect (Coren and Hoenig, 1972:Findlay, 1982: Ottes et al., 1985). For this to happen there are certain requirements that the stimuli have to meet. If a distractor is in the near periphery, with an eccentricity of less than 15° and within a 20° angular distance of the target (i.e. Heeman, 2011), it will most likely distract the eye movement away from the target. Hence the stimulus is interfering with the subject's task to move to the target. Stimuli at greater eccentricity or at greater distance of each other influence the latency of the saccade but not the landing position (Walker et al., 1997). Stimuli appearing within the 1.5° of the foveal region do not evoke an averaging effect (Vitu et al., 2006), thereby supporting the assumption that saccadic averaging is elicited by global information obtained from peripheral vision.

Vitu et al., (2006) propose that the global effect arises from poorly processed input. When attention is not yet shifted and stimuli commence in peripheral areas of one's visual field the whole area in and between the stimuli is seen as salient. Therefore an averaging effect is likely to occur. According to Vitu et al. (2006) the global effect disappears after 260-300ms when distractor and target are visually dissimilar and not in too close proximity. When distractor and target are more similar it takes more time for the global effect to disappear. The global effect happens without any thought or intention from the subject, implying that it needs to be a fast bottom-up action.

Godijn and Theeuwes (2002) proposed a competitive integration model, which assumes that the control signals for bottom-up and top-down controlled saccades converge on a common saccade map with a retinotopic representation in which information from different sources is integrated. Thus, a distractor that causes exogenous saccades as a distractor and endogenous saccades such as a task to move to a specific target are combined to one saccade action. When the distractor – the endogenous factor - appears near the target, the combined activation of the to saccade programs within the saccade map results in a high peak somewhere between the two locations (Godijn and Theeuwes, 2002).

There are several low-level properties that influence the strength of a target's distracting factor in measuring the global effect. These include: size (Findlay, 1982), a larger stimulus is seen as more salient, contrast (Deubel et al., 1988) and surface structure (Deubel et al., 1988). In general, the saccadic end-point is directed towards the more salient stimulus (Coren and Hoenig, 1972: Findlay, 1982).

In the last decades there have been several studies indicating that elements that are presented outside of awareness (subliminally) can nevertheless influence behavior (Ansorge et al., 1998: Breitmeyer et al., 2004: Kanai et al., 2006: Schmidt and Schmidt, 2010). These studies often address the distinctions between conscious and unconscious processing and the level of brain activity corresponding to them. A way to study these distinctions is by testing healthy subjects in an experiment where images are suppressed by visual masks in a way that conscious processing is taken away while unconscious processing of the stimulus remains. For example, metacontrast masking occurs when a temporally proximal but spatially non-overlapping stimulus (mask) impairs detection of a preceding target stimulus (Breitmeyer, 1984).

1 A distractor is a stimulus that is irrelevant to the subject's task but appears at or around the same moment as the target stimulus, creating a distractive element for the task.

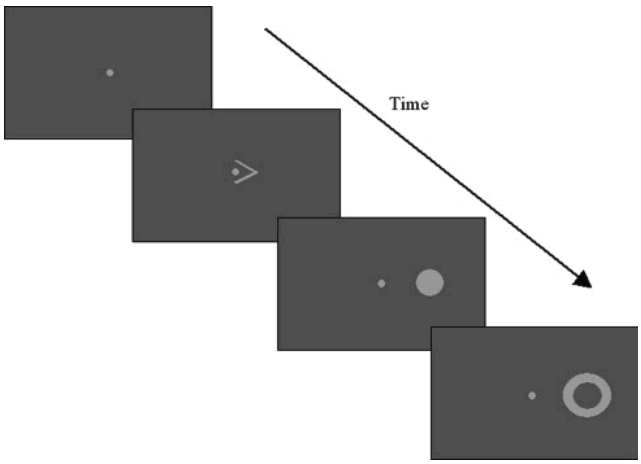

Figure 1. **Schematic illustration of the sequence of events of typical metacontrast masking (Boyer J, Ro T, 2007)**

Metacontrast masking has also been used by Tapia et al. (2010) to examine how two features of a stimulus, its form and color, are processed separately or jointly at the unconscious and conscious level. This study found that: (1) during unconscious processing a task-irrelevant stimulus feature can be attentionally filtered out. Thus, when primed to a certain color, the observer unconsciously pays less attention or ignores subliminally presented irrelevant colored primes. (2) During unconscious processing only separated stimulus features can be attended (initially found by Treisman and Gelade, 1980: Treisman, 1985: Treisman, 1998). From these studies, it can be concluded that subliminal information can influence our behavior. For example, when a distractor acts like a cue by appearing a moment earlier than other distracting stimuli, this will alter the reaction time of the observer (Van der Stigchel et al., 2009). But also, when an observer is primed to a certain color and stimuli with that color are subliminally presented, they can act as a cue to influence the observer's behavior in pointing towards a target (Schmidt and Schmidt, 2010). Additionally, in an experiment by Breitmeyer et al. (2004) it has been shown that color is in some way processed by the brain after 20ms. Nevertheless, it is not completely clear yet what kinds of aspect the stimuli have to have in common for eliciting a difference in the global effect.

The current experiment was designed to find a possible common denominator between the target and distractor that causes a subliminal influence on behavior. The color of a stimulus was suppressed by visual backward masking (Munting, 2006) to find out what influence it would have on the global effect compared to other conditions, such as different suppressed colors or supraliminal conditions. Before starting the main experiments, an awareness experiment was conducted with a different independent set of subjects in which the subjects had to report if they noticed the masked stimulus and what color it contained to find the conditions that rendered a stimulus invisible. The subjects needed at least 4 frames to even notice something was happening, still then they didn't know specifically that the color had changed. Only after 94ms (8 frames) the subjects scored above chance level in recognizing the masked stimulus' color. Observers had to be kept unaware of the subliminal target; this is why in the current experiment the subliminal stimulus is presented only 2 frames. Also as stated before the saccadic end-point tends to land near the more salient stimulus; this is why we kept the low-level properties (size, surface structure, intensity, etc.) equal between all stimuli. The only property that made a stimulus more salient was its color.

We used five different conditions in which the task was to make a saccade towards the target, which was a green circle: (1) Only a target appeared, (2) two targets appeared, (3) a target and a red distractor appeared, (4) a target and a yellow

target appeared which was masked by a red distractor, (5) two targets appeared but one of them was masked with a red distractor.
If, in the main experiment, the subliminal stimulus and its feature would be unconsciously processed, it is expected that the more salient stimulus would create a larger deviation towards this stimulus in the saccadic end-point. If unconsciously the subject would process the subliminally presented stimulus but not the specific color feature, a difference in the end-point could be measured, but this would probably not differ between the two subliminal conditions.

Method

Apparatus

A Macintosh with a processor speed of 2 GHz controlled the timing of the events. Displays were presented on a LaCie electron22blue III monitor with a resolution of 1024 × 768 pixels and an 85-Hz refresh rate. A second computer controlled the registration of eye movement data on-line. Eye movements were registered by means of a video-based eye tracker (SR Research Ltd., Canada). The Eyelink 1000 desktop Mount system has a 1000 Hz temporal resolution. Data from the left eye was monitored and analyzed. The viewing distance was 57 cm.

Stimuli

There were 5 conditions (figure 3):

- A baseline condition – called the 'target only condition' - including only a green target.
- Another baseline condition with a green target and a green distractor – called 'similar condition', both supraliminally presented.
- A condition with a green target and a red distractor – called 'dissimilar condition' – both supraliminally presented.
- A subliminally neutral condition. Here the red mask masked a yellow and neutral stimulus – the 'neutral first' condition.
- A subliminally congruent condition. Here an incongruent red mask masked a distractor that was green – the 'similar first condition'.

The distractor was masked making use of visual backward masking; the mask completely fills and perfectly fits the masked item, covering it 23.5ms (two frames) after onset. All stimuli, including those used for calibration and drift corrections, were displayed on a black background (0 cd/m2). A display consisted of a centered white fixation cross (0.60° in length and 0.04° in width), followed by one of the 5 target conditions - as described above - followed by a cyan refixation cross. The targets and distractors were circles with a diameter of 0.65°. All circles appeared on the outer boundary of an imaginary circle of 8° in diameter separated from each other (in case there was a distractor) by an angle of 9° out of the center with 8 possible positions all at a distance of 45° from either the horizontal or vertical line through the center of the screen (figure 2). The target was green with a luminance of 18 cd/m2 (x = 0.292; y = 0.607; u' = 0.120; v' = 0.563). The distractor was red with a luminance of 8.52 cd/m2 (x = 0.626; y = 0.341; u' = 0.428; v' = 0.526), green or yellow with a luminance of 18.6 cd/m2 (x = 0.420; y = 0.506; u' 0.204; v' = 0.553). In the latter two situations a red

circle masks the green or yellow circle, which it was for 2 frames. All colors were kept psychometrically isoluminant by heterochromatic flicker photometry.

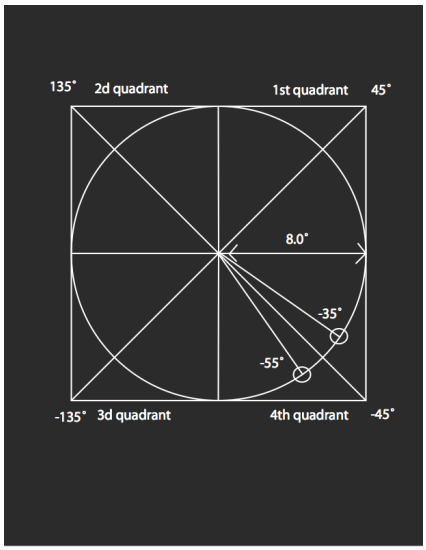

Figure 2. **Illustration of the corners and sizes the two circles represent a possible positioning of target and distractor. These pairs could appear in any quadrant.**

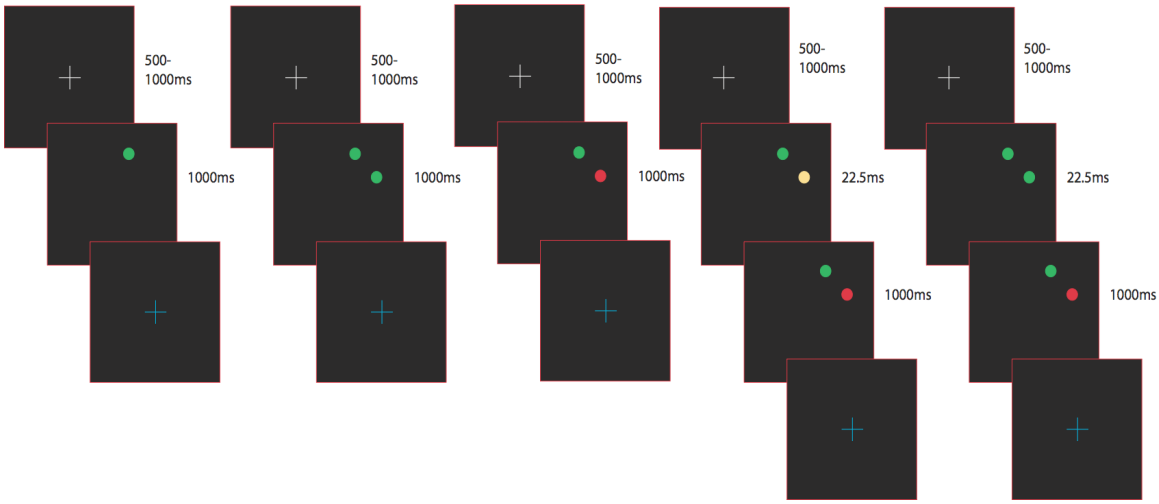

Figure 3. **From left to right all 5 conditions in the same order as described above.**

Awareness test

Observers

Three subjects participated in the awareness test: One of my supervisors, an employee of the faculty and myself. All were aware of both the purpose of my study and of this test in specific.

Task

The task was to try to identify the color of the masked stimulus. The observers were told to try to discriminate between yellow and green.

Test

Only the two subliminal conditions were used for this task. After the stimuli appeared a text appeared with “Links voor geel, rechts voor groen” which is Dutch for “Left for yellow, right for green”. The subjects were tested with a SOA of one frame (11.74ms) 2 frames, 4 frames and 8 frames.

Main Experiment

Observers

8 subjects with useable data participated in the experiments. 4 subjects conducted non-usable data because of faults in the experiment code. All participants were kept naive as to the purpose of the experiments. All observers reported normal or corrected to normal vision.

Experimental procedure

The experiment consisted of two sessions: One session with eye movements (*eye movement task*) and one session without eye movements (*distractor report task)*, which was identical to the aforementioned awareness test with the SOA permanently set at 2 frames.

First session

The task was to make an eye-movement towards a target stimulus as fast as possible after its onset. Observers were also told about the possibility of a red distractor or a green distractor. Observers were instructed to try to ignore the red distractor. Additionally, the observers were told to go to one of the two green stimuli if a green distractor appeared.
A calibration procedure was performed at the start of each session and a validation process was used to verify the accuracy of this mapping. Every 5th trial a drift correction interrupted the session to recheck this accuracy. During both procedures – the calibration and validation - observers were asked to move their eyes to the centre of a small spot, which appeared at nine locations on the monitor. The nine-point display covered a rectangular area with points representing the centre, the four corners and the mid-point of the four sides. Subjects completed 400 trials; each target condition appeared 80 times in a random manner on one of the 8 possible target positions. Additionally each possible target position appeared 50 times in a random manner.

Second session

The task of the participants was to identify and report the color of the masked item after each trial. They were told stay fixated on the fixation cross until it disappeared. Additionally, they had permission to try to focus on the distractor instead of focusing on the target. The session existed of 16 trials. Eight times the similar first condition and eight times the neutral first condition. A display was similar to a display in the main experiment described above. If the participant had more than 75% correct the subject was excluded from the data. In any case where there was more than 75% correct

the chances of the observer not guessing would be more than 5%.

Analysis

The angle deviation from the mid-point between the two stimuli, measured from the centre of the screen, was used to define the saccadic landing position. The axis, around which the stimuli are positioned, representing the midpoint between the stimuli was used as a null-reference, thus having a deviation with the value 0. When a saccade ended on the target or distractor stimulus, the deviation had the value 1 and -1 respectively (Heeman, 2011).

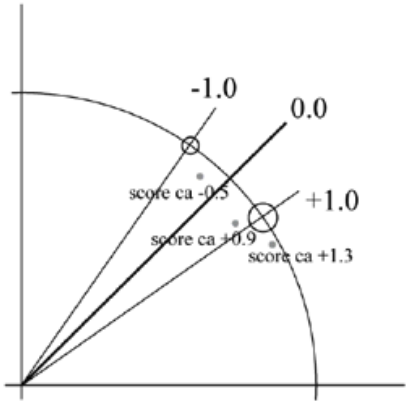

Figure 4. **Saccade landing position was defined as a proportion of the angle between the stimuli. The axis around which the stimuli are positioned, representing the midpoint between stimuli, was used as null-reference. Saccades landing on the axis were scored as having a deviation score of zero. Saccades landing on the target had a score of 1 and saccades landing on the distractor had a score of -1.**

The amplitude of the saccade was ignored in this study, apart from extremes (movements less than 50 pixels or 2 degrees from the centre), which were excluded from in the data-analysis. All landing positions in all quadrants were transferred and translated to one position at 3 o' clock and all angles were normalized to the target being 4.5° above the horizontal line and the distractor being 4.5° beneath the horizontal line. Certain restraints were put to exclude trials that were not representative to this research. Trials were removed when an eye movement was made just before the trial started. Additionally, trials were removed when the saccadic latency was smaller than 80ms or larger then 500ms. The saccadic latency was defined by the difference between target onset and the start of the saccade. Also, a trial was removed when an eye movement started with a visual angle larger than 2° either horizontally or vertically from the centre of the screen. The first restraint was set because it is hard to anticipate the eye movement when another eye movement is made just before the trial starts. The second restraint was set because eye movements that were too fast were most likely anticipatory or because eye movements were too slow and all visual information was processed before the initiation of the eye movement.

A total of four two-sample t-tests with regards to the saccadic latency were performed. According to earlier research the global effect gets weaker when saccadic latencies are higher (Vitu et al., 2006). So when a larger global effect would be found at conditions with lower saccadic latencies part of the effect might be attributed to the saccadic latency. Additionally a one-sample t-test was performed on the baseline condition (similar condition) as a check for the stimuli sizes and positions. Finally, to answer the main question in this study, three more two-sample t-tests were performed to compare the global effect between conditions.

Results

Based on the criteria presented above 264 out of 3200 trials were excluded (8.25%) with 17.25% exclusion being the largest percentage belonging to one subject.

Baseline condition

The one-sample t-test on the similar condition did not provide a significant effect ($t(7) = 0.575$, $p = 0.584$) indicating that the null hypothesis can not be rejected (M = 0.028, STD = 0.137) and again a global effect would most likely be found.

Comparing the subliminal conditions

No significant effect was found in the global effect comparing the two subliminal conditions ($t(7) = -0.920$, P = 0.388) (Similar first: M = -0.074, STD = 0.129. Neutral first: M = 0.016, STD = 0.197). In both cases a strong global effect elicited. No significant difference in landing positions between these two conditions is found and there is a slim chance this will be different if any subsequent observer would participate in the experiment. Additionally there was no significant effect found comparing the two subliminal conditions' latencies ($t(7) = 1.083$, P = 0.554) (Similar first: M = 126.719, STD = 6.455. Neutral first: M = 127.854, STD = 5.505).

Comparing the neutral first condition to the dissimilar condition

A significant effect was found comparing the landing positions of the neutral first condition to the landing positions of the dissimilar condition ($t(7) = 3.660$, P = 0.008) (Dissimilar: M = 0.494, STD = 0.230. Neutral first: M = 0.016, STD = 0.197). This result indicates that the neutral first condition does elicit a larger global effect.

A significant effect was found comparing the latencies in the same conditions ($t(7) = 14.814$, P = 1.530e-06) (Dissimilar: M = 155.683 STD = 7.158. Neutral first: M = 127.854, STD = 5.505), This result indicates that the subliminally presented stimulus has an influence on the reaction time of the observer and in specific makes the reaction time smaller.

Comparing the similar first condition to the dissimilar condition

A significant effect was found comparing the landing positions of the similar first condition to the landing positions of the dissimilar condition ($t(7) = 6.475$, P = 3.421e-04) (Dissimilar: M = 0.494, STD = 0.230. Similar first: M = -0.075, STD = 0.129). This result indicates that the similar first condition does elicit a larger global effect.

Similarly a significant effect was found comparing the latencies in these conditions ($t(7) = 16.639$, P = 6.921e-07) (Dissimilar: M = 155.683 STD = 7.158. Similar first: M = 126.719, STD = 6.455). Again indicating that the subliminally presented stimulus has an influence on the reaction time of the observer and in specific makes the reaction time smaller.

	Mean Global effect	Sd Global effect	Mean Latency	Sd Latency
Target only	2.059	0.147	159.767	8.987
Similar condition	0.028	0.137	157.462	9.284
Dissimilar condition	0.494	0.230	155.683	7.158
Neutral first	0.016	0.197	126.719	6.455
Similar first	-0.075	0.129	127.854	5.505

Table 1. **All global effect & latency values.**

	T(7) t-value with degrees of freedom 7	P value
Similar condition	0.575	0.584
Neutral first to similar first	-0.920	0.388
Neutral first to dissimilar	3.660	0.008
Similar first to dissimilar	6.475	3.421e-04

Table 2. **All global effects compared with t-tests**

	T(7) t-value with degrees of freedom 7	P value
Neutral first to similar first	1.083	0.554
Neutral first to dissimilar	14.814	1.530e-06
Similar first to dissimilar	16.639	6.921e-07

Table 3. **All latencies compared with t-tests**

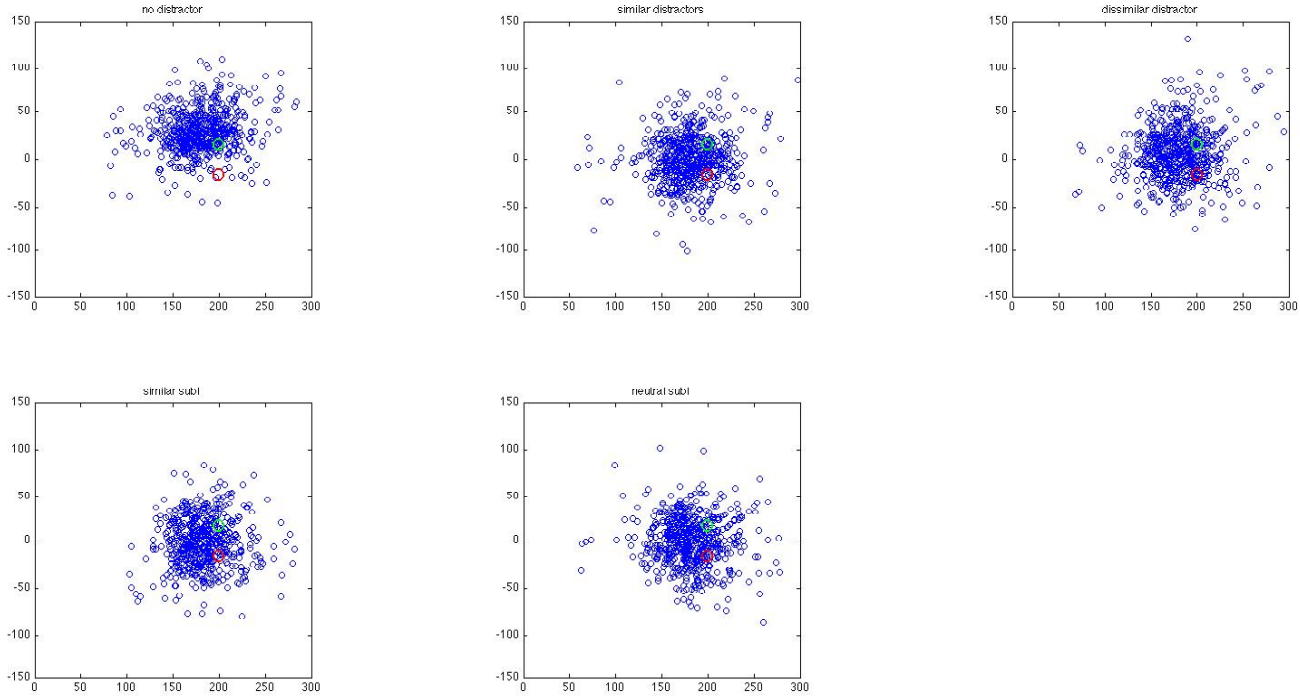

Figure 5. **Schematic illustration of all trials for each condition rotated to one side taken from one subject. The green circle represents the target and the red circle represents the distractor (no distractor, similar, dissimilar,**

similar first, neutral first; from left to right).

Discussion

The main question in this paper was: Is color a common denominator between the target and distractor that causes a subliminal influence on behavior with respect to the global effect? In this study a strong global effect was found when target and distractor have the same visual information, are in near periphery, in the same hemifield and close to each other. As is in accordance with other research (i.e. Findlay, 1982). Additionally, in all two-stimuli conditions a global effect was found. Also a significant difference has been found when presenting subliminal stimuli compared to supraliminal conditions. The subliminal conditions showed a stronger global effect. This would indicate that in some manner the subliminal information is processed. However, a significant difference in saccade latencies between subliminal and supraliminal conditions is found; the subliminal conditions were accompanied with significantly shorter saccade latencies than the supraliminal conditions. Keep in mind that a shorter saccadic latency elicits a stronger global effect (Vitu et al., 2006). Also, no significant difference in the strength of the global effect has been found comparing the two subliminal conditions. This indicates that the color has not been processed in a way to elicit a different behavioral response. Possibly, the reason the subliminal conditions elicit a stronger global effect is that the masking procedure is processed in a way in which it acts like a cue, but is not processed by its color. Because of this cue the response is faster and the saccadic latency is smaller. Finally, because the saccadic latency is smaller the global effect gets stronger.

Although color can in someway be processed after 20ms, (Breitmeyer et al., 2004: Tapia et al., 2010: Schmidt and Schmidt, 2010) the stimuli in this study do not seem to elicit the predicted neuronal response or behavior.

Possible reasons for the absence of a significant difference in the global effect between the two subliminal conditions are the size and peripheral distance of the stimuli. We used sizes that have proven to work in supraliminal and non-surface based properties. Schmidt & Schmidt (2010) for instance used slightly larger stimuli (around 1 visual degree in diameter) and presented in nearer periphery (imaginary circle of 4.675 visual degrees). Tapia et al. (2010) also used larger color based primes (0.86 x 0.86 visual degrees squares). Further visual properties, such as contrast and luminance differences between the stimuli, did not vary from other more successful studies. Schmidt and Schmidt (2010) for instance used the same method to achieve psychometric isoluminancy. They also used heterochromatic flicker photometry and they did find an unconscious response to color. Another difference between our study and Schmidt and Schmidt (2010) is the procedure of the experiment; their experiment was less vulnerable to minor luminance differences because in between unconscious priming and targeting there was an intermediate black screen. This way a small luminance difference is less conspicuous to the eye. Henceforth we conclude nothing yet, color might be processed unconsciously with different stimulus-properties but no effects have been found in this study.

Future investigations

The question now remains, does color influence behavior on an eye movement task when unconsciously processed. One future study should replicate what we have done here but with larger stimuli and the stimuli positioned in nearer periphery. This way a larger neuronal activation from the unconsciously processed colors might induce a different global effect between variant colors.

A second interesting study could investigate the differences in saccade latency between subliminal and supraliminal conditions. Minor luminance differences in the masking procedure could possibly induce capture saccades (Van der

Stigchel et al., 2011). Capture saccades are bottom-up processes in which a sudden onset of a stimulus creates a deviating saccade towards this stimulus. Bottom-up or automatic processes are often faster this could explain the significant differences in saccade latencies.

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