# PRIMING OF POP-OUT AND CONSCIOUS PERCEPTION

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## Abstract

*Research has demonstrated a striking role for recent experience in visual search. For instance, search for a singleton target is substantially speeded when either its defining feature or its location repeats on successive trials (Priming of Pop-out and Priming of Location, Maljkovic & Nakayama, 1994; 1996, respectively). Here, we investigated the role of conscious perception in inter-trial priming. Subjects searched for a shape singleton and reported its color. In each trial pair, we used backward pattern masking to induce liminal processing of the first search display while the second search display in the pair was clearly visible. Repetition of the target shape speeded search performance only when the target in the priming trial had been consciously perceived. Yet, search performance was above chance when the participants' failed to subjectively perceive the display, suggesting that some unconscious processing occurred. There was no location priming effect in any of the awareness conditions.*

Recent research has demonstrated a striking role for implicit visual memory factors in visual search performance (e.g., Maljkovic & Nakayama, 1994;, 2000). Maljkovic and Nakayama (1994) were the first to show that when there is uncertainty regarding the target feature, such as when the target is defined as the discrepant item in a homogeneous field of distractors, visual search performance is substantially improved when the target's discrepant feature happens to repeat from one trial to the next. They called this phenomenon ''Priming of Pop-out'' (PoP). In their experiments, participants searched for an odd-colored diamond, either a red diamond among green diamonds or a green diamond among red diamonds. That is, the target and distractor switched colors unpredictably from trial to trial. Repeated-color trials were faster than switched-color trials. This effect has been replicated with targets differing from the surrounding distractors by their shape (e.g., Lamy, Carmel, Egeth, & Leber, 2006), their orientation (e.g., Hillstrom, 2000), their emotional valence (Lamy, Amunts, & Bar-Haim, 2008) and their location (e.g., V. Maljkovic & K. Nakayama, 1996)

In the present study we investigated the role of conscious perception in inter-trial priming. Specifically, we asked whether the benefit of repeating the target feature on trial *n* is contingent on conscious perception of the target feature on trial *n-1*. Maljkovic and Nakayama (2000) suggested that the memory underlying the priming effect is implicit because their observers were unable to explicitly recall the color combination reliably beyond the immediately preceding trial. However, in their study, search displays were clearly visible and remained in view until the participants responded. Thus, while their findings suggest that conscious recollection of the target feature is not necessary for inter-trial priming, it is not informative as to the role of conscious perception in this effect. Recently, Kristjansson et al. (2005) examined whether inter-trial priming in neglect patients. Visual neglect is a condition that results unilateral brain damage in the parietal lobe. Neglect patients are characteristically unaware of the contralesional side of space, such that in visual search, they often fail to detect targets that appear in their contralesional field Kristjansson et al. (2005) used brief displays (200ms) in a search task similar to Maljkovic and Nakayama's (1994), while also requiring the patients to report whether or not they had consciously perceived the target on each trial.

Patients were unaware of the target in their affected hemifield on a substantial proportion of the trials. The results revealed that repetition of the target color (i.e., color PoP) was observed regardless of whether the target on the previous trial had been consciously perceived or had escaped the patients' awareness. By contrast, location priming occurred only when the patient had consciously perceived the target on the previous trial. They suggested that "color priming is likely to involve ventral visual pathways that may then interact with other centers affecting search, and such interactions may persist implicitly even without the patients' awareness" (p. 869).

Although these findings suggests that inter-trial priming of some properties can be preserved in the absence of conscious perception of the target in neglect patients, it is not clear to what extent this conclusion can be generalized to healthy patients. In addition, as neglect is thought to be an attentional deficit (Mesulam, 1981), it remains an open question whether PoP can be observed when conscious perception is prevented by degrading the stimulus rather than diverting the subjects' attention from it.

The objective of the current study was to examine this issue We used pattern visual backward masking (e.g., Breitmeyer & Ogmen, 2000) to impair conscious perception of the search display. While other forms of masking are thought to involve attentional processes (e.g., V. Di Lollo, Enns, Rensink, & V. D. Lollo, 2000) pattern masking is thought to involve integration between the target and mask and therefore to degrade the quality of the stimulus (B. Breitmeyer, H. Ogmen 2006) In order to assess whether Kristjansson et al.'s (2005) findings can be generalized to other properties coded in the ventral visual pathways, we investigated PoP for shape instead of PoP for color.

In the present experiment, subjects searched for a unique letter shape (the target) among homogenous letters (the distractors) and reported its color. Trials were organized in pairs such that the first trial in a pair involved a backward masked search display whereas in the second trial, the search display remained in view until the subjects responded. The time interval between the search display and mask in the masked-display trials was individually adjusted for each subject in order to obtain liminal processing of the stimulus, (i.e., for subjects to report being subjectively aware of the target shape on roughly 50% of the trials). The question of interest was whether repeating the target shape or location on successive trials within a pair would speed search performance (1) when the priming display had been masked but the target had nonetheless been consciously perceived and (2) most crucially, under the exact same stimulus conditions but when the target had escaped the subjects' awareness.

If the findings obtained with neglect patients can be replicated when conscious perception of the target is prevented by pattern masking in healthy subjects, we should observe PoP for shape irrespective of subjective perception and priming of location only when the target has been consciously perceived in the priming display. In line with previous studies (see Merikle, Smilek, & Eastwood, 2001 for a review), we also expected missed target to undergo some unconscious processing that is, we expected above-chance performance accuracy on masked-display trials.

## Method

*Participants*

Eighteen observers (8 males) 20-30 of age volunteered to participate. All reported normal or corrected-to-normal visual acuity and normal color vision.

*Apparatus*

Displays were generated by an Intel Pentium IV computer using by E-prime software. The stimuli were presented on a 17-inch color monitor, using 1024 × 768 resolution graphics mode with 85Hz refresh rate. Responses were collected via the computer keyboard. A chin-rest was used to set viewing distances to approximately 50 cm from the monitor.

*Stimuli*

The fixation display was a gray 0.2° × 0.2° plus sign (+), in the center of a black background. The priming display consisted of six uppercase letters (1° in length and 0.8° in width) that were either blue (RGB 130, 39, 152) or yellow (RGB 149, 54, 56). Each display contained one unique letter, the target, among 5 same-letter distractors. The two different letters that appeared in each display were randomly selected from a set of 14 letters (A, E, H, I, K, L, M, N, T, V, W, X, Y, Z). The letters appeared within an imaginary 3 × 3 matrix, with each cell subtending 2.4 deg. of visual angle in side. Each letter was centered inside its cell with a random jitter of up to 0.15°. Each display included exactly three blue letters and three yellow letters. The masking display was similar to the priming display except that both the target and distractor letters which had appeared in the priming display were superimposed in each of the filled location and were of the same color as the single letter that had appeared at that location.

The probe display was similar to the priming display: it also contained one unique letter, the target, among 5 same-letter distractors. The two letters were the same as those selected in the priming display, but their assignment to the roles of target and distractors either remained the same or reversed.

*Procedure*

Trials were organized in pairs, each containing a masked-display trial followed by an unmasked-display trial. On each trial, the fixation display appeared for 500ms. On masked-display trials, it was immediately followed by the priming display which remained visible for an individual exposure time duration determined during the calibration block, described below. Then, the masking display was presented until the participant's first response. It was replaced with a question mark that appeared until the participants' second response, which triggered the beginning on the unmasked-display trial. On unmasked-display trials, the fixation display was followed by the probe display that remained on the screen either until the participant's response or for 3000ms, whichever came first.

On each trial, the participants had to make a forced-choice response as to whether the unique letter (the target) was blue or yellow by pressing the appropriate keys as fast as possible, while maintaining high accuracy. Key-to-response mapping was counterbalanced between participants. On masked-display trials, participants had to produce an additional response, following the question mark display. Using their left hands, they had to report whether (1) they had clearly seen the target letter in the priming display by pressing "z", (2) they had been unable to discriminate it by pressing "c" or (3) were unsure about whether or not they had seen the target by pressing "x". Thus, there were three possible awareness responses (henceforth, "aware", "unaware" and "unsure", respectively).

The experiment began with a calibration block. Calibration trials were identical to experimental trials except that priming display duration was varied according to the participant's awareness report. Initial duration was set to 200ms Using a staircase procedure, priming display duration was decremented by 13ms if the participant had made an 'aware' response on the previous trial, and incremented by 13ms if the participant had made either an 'unaware' or a 'not sure' response. The mean duration across 40 trials was saved as the individual exposure time to be used in the experimental phase.

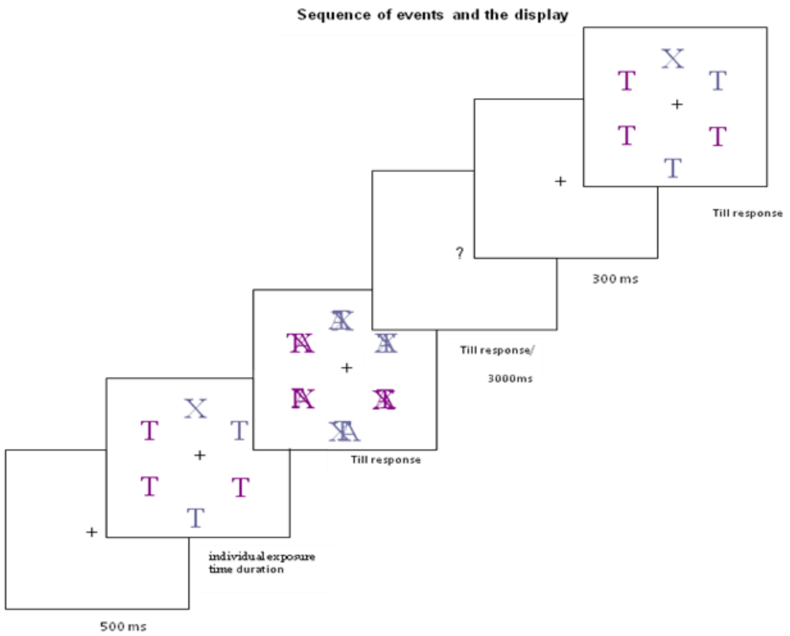

Fig 1: Sample sequence of events and search displays.

*Design*

The independent variables of interest were letter repetition from the priming to the probe display (repeated shape vs. switched shape), target location repetition (repeated location vs. switched location) and awareness response (aware, not sure, or unaware). The dependent variables were the mean latency and accuracy of the participants' responses to the target color in the probe display.

All possible letter pairs were equiprobable and each of the letters had an equal probability (p=0.07) to appear in a given trial pair. In the probe display, the target and distractor letters were equally likely to repeat or switch. In order to prevent priming effects between unmasked display trials separated by a masked-display trial, a minimum of 4 trial pairs separated repetition of the same letter between trial pairs.

The experiment began with a block of 40 calibration trials which also served as practice trials, followed by 10 blocks of 30 trials each. Participants were allowed a short rest after each block.

## Results and Discussion

Four participants were excluded from the analysis. One participant did not follow task instructions, as he failed to provide awareness reports; two participants made more than 35% of errors on their responses to the priming display despite reporting being clearly aware of the target shape; one participant's mean RTs exceeded the mean RT by more than 2.5 standard deviations. Trial pairs in which the subjects made an incorrect response on the probe trial (4% of all trials) were excluded from the RT analyses and so were trials with RTs exceeding the mean RT by more than 2.5 standard deviations (5% of all trials).

*Letter-repetition analysis*

An Analysis of Variance (ANOVA) with letter shape repetition (repeated vs. switched) and awareness (aware vs. unaware) was conducted on mean RTs to the probe (unmasked-display) trials. Trial pairs in which the subjects reported being unsure of whether or not they had seen the target letter in the priming display were excluded from the analysis. The main effect of awareness was significant, $F(1, 13) = 8.53$, $p < 0.003$: RTs were faster when the participants had been aware of the target shape on the previous (priming) trial than when they had not, 1211ms, SD = 464ms vs. 1332ms, SD = 510ms, respectively, $F(1, 13) = 8.53$, $p < 0.003$. The main effect of letter shape repetition was not significant, $F < 1$. The interaction between the two factors was significant, $F(1, 13) = 3.83$, $p < 0.04$. Paired comparisons showed that the PoP effect was significant only when the participant had consciously perceived the target on the previous trial, $F(1, 13) = 4.09$ $p < 0.0045$ but not when they had reported not being aware of it, $F < 1$.

*Target location repetition analysis*
An ANOVA with location repetition (same vs. different) and awareness (aware vs. unaware) was conducted on the mean RTs. Trial pairs in which the subjects reported being unsure of whether or not they had seen the target letter in the priming display were excluded from the analysis. The main effect of awareness was again significant, ($F(1, 13) = 5.89$, $p < 0.02$). However, the location repetition effect was non significant, whether or not the participants had been aware of the letter shape in the previous (masked-display) trial, (all Fs < 1).

*Unconscious processing of the priming display*
Next, we analyzed the participants' performance accuracy at discriminating the color target letter in the priming (masked) display as a function of their awareness report in order to determine whether the target was unconsciously processed (Table 1). In the absence of such unconscious processing, the finding that PoP does not occur when participants are unaware of the target shape would not be surprising.

Table 1. Search performance on masked-display trials

| Awareness condition | Accuracy % |
|---|---|
| Aware | 89 |
| Not sure | 67 |
| Unaware | 59 |

Accuracy was better when the participants reported being aware of the target than when they were unsure, $t_{(13)}=7.16$, $p <0.0001$ and when they were unsure than when they reported being unaware of the target, $t_{(13)}=1.81$, $p <0.05$. Crucially, accuracy was above chance when the participants reported being unaware of the target, $t_{(13)}=7.27$, $p <0.0001$, indicating that some unconscious processing of the target took place.

Thus, the results show that PoP of shape is contingent on conscious perception of the priming target. As we failed to replicate the basic priming of location effect, we cannot assess the role of conscious perception in this effect.

## Conclusions

The main finding of the present study is that PoP of shape is contingent on conscious perception of the target in the priming display. Indeed, with identical search displays presented for the exact same duration on trial *n-1*, the effects of repeating the target shape on trial *n* changed dramatically depending on whether or not the observers reported consciously perceiving the target in the masked display on trial *n-1*. This result is clearly at odds with the findings reported by Kristjansson et al.'s (2005) with neglect patients. It will be important to determine the critical factor accounting for this discrepancy in future research. In particular, in may be useful to compare the roles of attention and stimulus quality in inter-trial priming without awareness of the priming target, as well as potential differences between intertrial priming of color vs. of shape. There was no PoP effect for location and there was PoP for shape only in the aware trials.

Those findings demonstrate the essentiality of subjective awareness and strong implicit process to the PoP phenomenon. In contrary to regular priming effect, there was no facilitation of subliminal priming on a visual search task in unaware condition. Those findings suggest that PoP process is not utterly implicit and it requires some sense of awareness (even minimal awareness like in shift of attention masking).

## References


Breitmeyer, B. G., & Ogmen, H. (2000). Recent models and findings in visual backward masking: a comparison, review, and update. *Perception & psychophysics*, *62*(8), 1572-1595.

Hillstrom, a P. (2000). Repetition effects in visual search. *Perception & psychophysics*, *62*(4), 800-817.

Kristjánsson, A., Vuilleumier, P., Malhotra, P., Husain, M., & Driver, J. (2005). Priming of color and position during visual search in unilateral spatial neglect. *Journal of cognitive neuroscience*, *17*(6), 859-873.

Lamy, D., Amunts, L., & Bar-Haim, Y. (2008). Emotional priming of pop-out in visual search. *Emotion (Washington, D.C.)*, *8*(2), 151-161.

Lamy, D., Carmel, T., Egeth, H. E., & Leber, A. B. (2006). Effects of search mode and intertrial priming on singleton search. *Perception & psychophysics*, *68*(6), 919-932.

Di Lollo, V., Enns, J. T., Rensink, R. A., & Lollo, V. D. (2000). Competition for consciousness among visual events: the psychophysics of reentrant visual processes. *Journal of experimental psychology. General*, *129*(4), 481-507.

Maljkovic, Vera, & Nakayama, K. E. N. (1994). Priming of pop-out: I. Role of features. *Memory & cognition*, *22*(6), 657-72. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7808275

Maljkovic, V., & Nakayama, K. (1996). Priming of pop-out: II. The role of position. *Attention, Perception, & Psychophysics*, *58*(7), 977–991. Springer.

Maljkovic, Vera, & Nakayama, Ken. (2000). Priming of popout: III. A short-term implicit memory system beneficial for rapid target selection. *Visual Cognition*, *7*(5), 571-595.

Merikle, P. M., Smilek, D., & Eastwood, J. D. (2001). Perception without awareness: perspectives from cognitive psychology. *Cognition*, *79*(1-2), 115-34.

Mesulam, M. M. (1981). A cortical network for directed attention and unilateral neglect. *Annals of Neurology*, *10*(4), 309-325.