Spatial distance between target and irrelevant patch modulates detection in a texture segmentation task

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Abstract—In three texture segmentation experiments a target patch had to be detected. We studied the impact of a task-irrelevant patch in the backward mask on detection performance, and especially the modulating effects of its spatial distance to the target. It was assumed that the signals of the two texture irregularities interact as a function of their spatial distance. Experiment 1 revealed that the task-irrelevant patch impaired target detection only when the distance was small. In Experiments 2 and 3 with systematically varying distances, detection performance increased linearly with distance until a maximum point. If the task-irrelevant patch appeared outside of a *critical distance*, performance did not increase further with increasing distance. Our findings are discussed in terms of the biased competition account. It is proposed that the *critical distance* may correspond to the average receptive field size of a cortical area that is critical for target detection.

Keywords: Early vision; texture segmentation; saliency; receptive field size; retinotopic organization.

1. INTRODUCTION

Studying early vision processes often involves texture segmentation tasks with a so-called pop-out target. Stimuli are homogenous textures (e.g., tilted lines) containing a texture patch (target) with a predefined probability. The elements of the target texture differ from the context elements by one or more basic features (e.g., orientation; cf. Fig. 1a). This kind of target ‘pops out’, i.e., its detection happens quasi-effortlessly and automatically (Wolfe, 1998).

Usually, in experimental studies, the target patch that has to be detected is the unique irregularity in the stimulus. Compared to natural environments, this creates a rather artificial stimulus situation: When searching a relevant target in the real world, one encounters a lot of task-irrelevant irregularities in the visual scene that pop-out. In the present study, we wanted to explore the influence of a second,

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Figure 1. Experiments 1 and 2: (a) Stimulus with target patch; (b) Mask with irrelevant patch. (a) and (b): The number of elements has been reduced for better visualization of the texture structure. For the same purpose the luminance contrast in this figure has been increased compared to the original stimuli.

task-irrelevant texture patch on target detection. The results should give us more information about the nature of detection processes in pop-out tasks. Itti and Koch (2001) (see also Nothdurft, 2000) presented a (computational) model describing the automatic detection of pop-out targets. They propose a two-dimensional saliency map, which represents all salient locations within a texture. Thus, a target patch in a texture produces an enhanced activity on the saliency map. This activity signal is evaluated by a detection process, e.g., by directing the spotlight of attention to this location (see also the concept of ‘attentional capture’ by Theeuwes, 1994). A task-irrelevant patch, however, should also lead to an activity on the saliency map. This second, but task-irrelevant signal could interfere in some way with the detection of the task-relevant signal. Our aim is to gather more information about this possible interference.

The impact of task-irrelevant signals on detection performance has already been studied in the context of visual search tasks (e.g., Ester and Awh, 2008; Forster and Lavie, 2008; Hickey *et al.*, 2006; Mounts, 2000; Müller *et al.*, 2008; Theeuwes and Chen, 2005; Theeuwes *et al.*, 2004). The general finding is that task-irrelevant salient objects can in fact deteriorate performance (e.g., discrimination or identification of singletons). Processes of visual search are possibly based on analogue mechanisms as texture segmentation. But Wolfe (1992) showed that they should not be considered as identical (see also Schubö *et al.*, 2004, for differences between visual search and texture segmentation). Concerning texture segmentation tasks, some first results are reported that a task-irrelevant feature variation in the stimulus can have an impact on segmentation performance (e.g., Callaghan, 1989; Callaghan *et al.*, 1986; Gurnsey *et al.*, 1992; Meinecke and Donk, 2002). Meinecke and Donk (2002) presented participants a 9×9 (imaginary) matrix of tilted line elements. One-half of the trials contained one orthogonally oriented line (the target) that had to be discovered. In condition ‘81’, all cells of the imaginary matrix were filled with a line. In condition ‘80’, in each trial one randomly selected cell remained empty. Although this empty cell was not task-relevant, a significantly poorer performance was observed. The empty cell presumably constituted a second irregularity that could not be ignored. Schubö *et al.* (2001) provided physiological evidence (event related potentials, ERPs) demonstrating that irrelevant texture patches are encoded automatically in texture segmentation tasks. Observers were confronted with orientation textures (tilted lines) for a few milliseconds, with a small circle superimposed in the center of the screen. The task was to decide whether the circle was filled or unfilled. In some trials the stimulus texture additionally contained a task-irrelevant discontinuity (a 3×3 patch with lines tilted in the opposite direction). This discontinuity of the stimulus was not mentioned to the participants. Although participants reported that they did not notice any discontinuity, ERP effects have been found: stimuli with irrelevant patches led to an increased negativity of the N2p. Heinrich *et al.* (2007) also delivered physiological evidence supporting the idea that task-irrelevant texture patches were segmented automatically.

In sum, there is first evidence that a task-irrelevant signal can have an influence on performance in texture segmentation. The present study intended to gather further information about this influence, particularly by considering the spatial distance between the two irregularity signals, i.e., between the task-relevant and the task-irrelevant signal. As the cortical areas of the visual system are supposedly organized in a retinotopic manner (*cf.* Desimone and Gross, 1979), we assume that the spatial distance has a modulating effect on performance: a small distance between the two signals should have a higher impact than a large distance, because it should be more difficult to discriminate between the two signals when they are spatially close together. In accordance with the findings of visual search studies (e.g., Mounts, 2000; Theeuwes and Chen, 2005; Theeuwes *et al.*, 2004), where the impact on performance of a spatially close distracter was higher than of a spatially more distant distracter, we expected a stronger impairment of performance in the presence of a nearby irrelevant patch than of a more distant irrelevant patch.

Stimuli were constructed to meet the following requirements: the distances between task-relevant and task-irrelevant texture discontinuities should be varied, with an overlapping of both patches included. To ensure that the two patches can overlap without changing the structure of the target elements, we inserted the task-relevant target patch into the stimulus texture and the task-irrelevant patch into the backward mask. As stimulus presentation was short (e.g., < 100 ms), both saliency signals should have been represented on the saliency map almost synchronously. A target eccentricity of $\pm 9^\circ$ of visual angle was chosen, because this made it possible to vary the distance between the two texture irregularities over a large space of the visual field (from 0° up to 18° of visual angle).

Our first research question was: Does a task-irrelevant texture patch in the backward mask impair the detection of a task-relevant target? We expected a general decline of performance in the presence of a task-irrelevant patch, compared to its absence. Our second question was: Does the spatial distance between target patch and task-irrelevant patch modulate detection performance? We expected a proportional relationship between spatial distance and detection performance: The smaller the distance between target patch and task-irrelevant patch, the more performance should decrease. In the following we refer as ‘distance’ to the spatial distance between the target in the stimulus and the task-irrelevant patch in the mask. The present study comprises the data of a pilot experiment and of a subset of two large databases that have been created in the context of a research project.

2. EXPERIMENT 1: TASK-IRRELEVANT PATCH IN THE MASK

Experiment 1 was designed to study the impact of a task-irrelevant patch on detection performance in the context of texture segmentation. Participants were confronted with orientation textures that are well-investigated stimuli in texture segmentation experiments. The task was to detect a target patch that was presented on half the trials. Since previous studies have given evidence that targets on

Table 1.

Experiments 1–3: Possible positions of the target patch and the task-irrelevant patch on the horizontal meridian of the stimulus, respectively, of the mask

		Patch position (eccentricity in degrees of visual angle)																		
		−9	−8	−7	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9
Target patch (stimulus)	Exp. 1																			
	Exp. 2																			
	Exp. 3																			
Task-irrelevant patch (mask)	Exp. 1	×	×							×	×	×						×	×	
	Exp. 2																			
	Exp. 3	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×

peripheral eccentricities are easily detected with this type of stimulus (e.g., Kehrér, 1987, 1989), the target patch was positioned at the horizontal meridian on $\pm 9^\circ$ of retinal eccentricity. Furthermore, Experiment 1 was supposed to investigate the effect of varying the distance between task-relevant and irrelevant patch. In condition ‘patch’, large and small spatial distances were created by inserting a task-irrelevant patch into the mask texture at seven positions (-9° , -8° , -1° , 0° , $+1^\circ$, $+8^\circ$, $+9^\circ$; cf. Table 1) that resulted in four eccentricities (0° , $\pm 1^\circ$, $\pm 8^\circ$, $\pm 9^\circ$). In condition ‘no patch’, the mask did not contain a task-irrelevant patch and, thus, exhibited a homogenous texture.

2.1. Method

2.1.1. *Participants.* Six female and two male subjects were either paid or received course credit for participating in the experiment. They were between 20 and 38 years old and mean age was 25 years. All participants had normal or corrected-to-normal vision.

2.1.2. *Apparatus.* The experiment was run on a Power Macintosh G4 computer, with stimuli presented on an Iiyama HM 704 UTC monitor at 85 Hz (screen resolution of 1024×768 pixels). Stimulus presentation was controlled by a MATLAB program using the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). Luminance was measured with a Minolta luminance meter (model LS-110). Visual acuity was tested by a Rodenstock R22 vision tester, stimulus no. 212. Observers sat at a table on which a head-and-chin rest was mounted. Viewing distance was 450 mm, with the direction of gaze inclined slightly downward. Participants responded to the stimuli by pressing one of two mouse buttons with the index finger of either hand.

2.1.3. *Stimuli.* The stimuli were displayed on a screen of $39.6^\circ \times 30.2^\circ$ ($324 \text{ mm} \times 243 \text{ mm}$). The stimuli consisted of 3869 elements: 73 in the horizontal direction and 53 in the vertical direction subtending a visual angle of $36.6^\circ \times 26.5^\circ$

(953×693 pixels, see Fig. 1a). The elements were 45° tilted lines of 9 pixels length. The distance between adjacent line elements was 13 pixels horizontally and vertically. The target patch ($1.5^\circ \times 1.5^\circ$) was made up of 3×3 elements whose orientation was orthogonal to that of context elements. Whereas the vertical position of the target patch was held constant in the middle of the context, the horizontal position was varied. Patch position was determined by the position of its central element. The target could appear at two positions ($\pm 9^\circ$ visual angle). The lines were black (0.33 cd/m^2) and the screen background was gray (30 cd/m^2). A jitter randomly displaced the position of each texture element by zero, one or two pixels (in horizontal and/or vertical direction). The elements of the mask (see Fig. 1b) consisted of superimposed context and target lines forming $\times$ -like figures. The texture of the mask version in condition ‘no patch’ was homogenous, i.e., it contained no patch. The seven mask versions in condition ‘patch’ contained a task-irrelevant patch, which consisted of 3×3 elements ($1.5^\circ \times 1.5^\circ$), analogous to the target patch in the stimulus. The elements of the irrelevant patch were $+$ -like figures that were composed of two orthogonally superimposed lines, with a length of 9 pixels. The horizontal–vertical pixel arrangement of the $+$ -elements produced a darker impression than the diagonal arrangement of the $\times$ -figures. Thus, the impression of darkness of both elements was adjusted by raising the luminance of the $+$ -figures to 3.3 cd/m^2 . The position of the task-irrelevant patch in the mask varied on four eccentricities along the horizontal meridian (0° , $\pm 1^\circ$, $\pm 8^\circ$, $\pm 9^\circ$ of visual angle). All other parameters were as those of the stimuli. The target patch as well as the task-irrelevant patch was presented both to the left and to the right of the stimulus center. Table 1 shows the realized positions of the target patch (stimulus) and the irrelevant patch (mask).

2.1.4. Procedure. Two sessions were administered on two different days, each session lasting approximately 50 min. In the first training session, the two possible target positions ($+9^\circ$, -9°), but only a homogenous mask could appear. Data from training were not analyzed further. The experimental session started with two short practice blocks of 64 trials each. Five experimental blocks followed, each block with ten practice trials on its start. Each experimental block consisted of 128 experimental trials, 64 positive (target) trials and 64 negative trials (no target). The trials of the conditions ‘no patch’ and ‘patch’ were ordered randomly within a block. In positive trials the target appeared 32 times at a retinal position of $+9^\circ$ and 32 times at -9° . A backward mask followed the stimulus in all trials. Each of the eight mask versions (seven of condition ‘patch’ with task-irrelevant patch, one of condition ‘no patch’, homogenous, see Table 1) appeared 16 times. Each possible combination of task-irrelevant patch position and target position appeared four times in each block. In practice blocks, each combination appeared only twice. All trials were presented in random order. Each trial started with a small circle (diameter of 11 pixels) at the center of the screen informing the participant that he or she could start the stimulus display by simultaneously pressing both mouse buttons. The circle was

replaced by a fixation point (2×2 pixels), and after 800 ms the stimulus followed. To avoid ceiling or floor effects, presentation times of the stimuli were adapted to each participant's individual detection skills and ranged from 35.4 to 59.0 ms (mean = 45.7 ms). Presentation time was kept constant for each person throughout the experiment. For statistical analysis, the data were averaged over all participants and over all sessions. Thus, the varying presentation times were not critical. The mask remained on the screen until the participant responded by pressing either the left button (no target present) or the right button (target present). A short, single acoustic click informed the participant that his or her response was correct; a short double click that she or he had made an error. Then the circle was displayed on the screen again, indicating that a new trial could be initiated. Participants were requested to maintain central eye fixation, to respond as quickly as possible and to keep false alarms at a minimum. They were instructed to give a 'yes'-response only when they were highly certain that the stimulus contained a target. The purpose of this instruction was to keep individual differences in criterion as low as possible. Since the hit rate varied as a function of the spatial distance between the task-irrelevant patch and the target, participants could define their criterion only in relation to negative trials (trials without a target). As proposed by Treisman and Watts (1966) (see also Neyman and Pearson, 1933), in such an experimental situation in which the signal strength varies within the experimental condition, it makes sense to use only the false alarm rate as instruction for the participants to set their criterion. Independent variables were the seven mask versions in condition 'patch' and the homogenous mask in condition 'no patch'. Dependent variables were hit rate and false alarm rate. Reaction times were measured in order to identify and exclude outlier trials from the statistical analysis.

2.2. Results and discussion

For each participant, all trials in which reaction time exceeded the mean for that block by three standard deviations, were dropped from further analyses. We applied this procedure in all experiments. *t*-Tests (two-tailed) for paired samples and ANOVA for repeated measures were calculated to compare the means in all cases. Comparing the distance effects we analyzed the hit rate. Since the false alarms could not be attributed to one of the two possible target positions (in the left and in the right side of the visual field), d' could not be calculated. For *t*-test effect sizes we calculated Hedges g ; for *F*-test effect sizes we report partial eta square (ηp^2).

In condition 'patch', the false alarm rate was significantly higher as compared to condition 'no patch' (M (patch) = 8.75; M (no patch) = 3.59; $t(7) = 2.47$; $p < 0.05$; $g = 1.41$); the hit rate difference just failed to reach statistical significance (M (patch) = 62.86; M (no patch) = 69.06; $t(7) = 2.34$; $p = 0.52$; $g = 0.54$). The general comparison of the hits and false alarms in condition 'patch' vs condition 'no patch', however, should be interpreted cautiously. Due to the paradigm of this experiment and also of the experiments described below, one cannot exclude the possibility that the two texture irregularities were confused by their similar form and

because they could have identical positions ($\pm 9^\circ$) in the stimulus. The false alarm rate might be overestimated in the ‘patch’ conditions, because the task-irrelevant patch has been confused with the target (erroneous ‘yes’-answers). The hit rate difference might have failed to reach significance, because it was underestimated in the ‘no patch’ conditions. As the observer perceived only one texture irregularity in the ‘no patch’ conditions, she or he could have misinterpreted the target as a task-irrelevant patch (erroneous ‘no’-answers). Therefore, we report the data of the ‘patch’–‘no patch’ comparison, but exclude them from further interpretation in this experiment and also in the following experiments of this study.

Figure 2 presents the mean percentage of hits in condition ‘patch’ as a function of distance. An ANOVA for repeated measures on the factor distance showed a significant effect of distance ($F(6, 42) = 10.43$, $p < 0.01$, Greenhouse–Geisser corrected; $\eta p^2 = 0.60$). A trend analysis on this effect showed that the linear approximation on these data reached significance ($F(1, 7) = 18.24$, $p < 0.01$; $\eta p^2 = 0.72$), indicating that performance improved with increasing distance. A quadratic trend also reached significance ($F(1, 7) = 8.03$, $p < 0.05$; $\eta p^2 = 0.53$), indicating that the function of the hit rate increased until a maximum point. The function appears to asymptote at very large distances, suggesting little or no interference by the task-irrelevant patch with large distances to the target.

In short, the hit rate was reduced substantially in those cases where both patches were completely or partly overlapping. There was considerable variation depending on the spatial distance between task-irrelevant patch and target patch. The hit rate increased with increasing distances, but with very large distances, the effect of the task-irrelevant patch seemed to disappear.

Figure 2. Experiment 1: Hits (%) as a function of the distance (degrees of visual angle) between target patch and task-irrelevant patch. Bars show standard errors.

3. EXPERIMENT 2: EQUALLY SPACED VARIATION OF DISTANCE

Experiment 2 was designed to replicate our findings from Experiment 1 and to analyze in more detail the influence of the spatial distance between target patch in the stimulus and task-irrelevant patch in the mask. The relation between the effects of a task-irrelevant patch and its spatial distance to the target needs to be studied in more depth. Would detection performance increase proportionally to increasing distance? To close the gaps in Experiment 1, the spatial distance between the target and the task-irrelevant patch was varied systematically and gradually (see Table 1). Within a research project, a large database was created, comprising 19 target-patch positions and 19 task-irrelevant patch positions from -9° up to $+9^\circ$ of visual angle, respectively. Each condition comprised one target eccentricity, where two target positions (e.g., $+9^\circ$ and -9°) and 19 task-irrelevant patch positions (from -9° up to $+9^\circ$, equally spaced in 1° steps) were realized. Thus, the database of the project comprises ten conditions (condition '0°' up to condition ' $\pm 9^\circ$ '). Each of these conditions was tested block wise in two experimental sessions, lasting 50 min each, on two different days. For the present research question, we analyzed the data of the target positions $\pm 9^\circ$ only.

3.1. Method

3.1.1. Participants. Six female and two male students were paid to participate or received course credit. Ages were 20–37 years and mean age was 23.6 years.

3.1.2. Apparatus. The apparatus was identical to that in Experiment 1.

3.1.3. Stimuli. In order to parallel the location of target eccentricity in Experiment 1, we selected the condition ' $\pm 9^\circ$ ' out of the database. Thus, the target could appear at $+9^\circ$ or -9° of eccentricity (*cf.* Table 1). As in Experiment 1, the position of the target and the task-irrelevant patch varied only along the horizontal median. Now, the task-irrelevant patch could appear (in 1° steps, equally spaced) between $\pm 9^\circ$ of eccentricity. All other parameters concerning the structure and the elements of the stimuli as well as the masks were identical to those in Experiment 1.

3.1.4. Procedure. For the purpose of creating the database, twenty sessions were administered, each lasting approximately 50 min. In the first training session, all possible target positions, but only a homogenous mask could appear. The training data were not analyzed further. In the following 19 experimental sessions, ten target eccentricities (0° , $\pm 1^\circ$, $\pm 2^\circ$, $\pm 3^\circ$, $\pm 4^\circ$, $\pm 5^\circ$, $\pm 6^\circ$, $\pm 7^\circ$, $\pm 8^\circ$ or $\pm 9^\circ$) were realized block-wise, each encompassing two sessions (except target eccentricity 0°). The sequence of the presented target positions was permuted and balanced across subjects. Each target eccentricity was tested in two subsequent sessions on two different days. Each session started with two short training blocks (80 trials) and continued with five experimental blocks (170 trials). Each experimental block started with ten randomly selected training trials followed by 160 experimental trials, 80 posi-

tive (target) and 80 negative (non-target) trials. Each of the 20 backward mask versions (19 mask versions of condition ‘patch’, and one mask version of condition ‘no patch’) appeared eight times. In positive trials, the target appeared 40 times at each of the two possible retinal positions (on the left and on the right side of the stimulus). All possible target-mask-combinations appeared twice in experimental blocks, in practice blocks each combination appeared only once. All trials within a block were presented in random order. To avoid ceiling or floor effects, presentation times of the stimuli were adapted to each participant’s individual detection skills and, thus, varied in condition ‘ $\pm 9^\circ$ ’ between 23.6 ms and 58.8 ms (mean = 38.2 ms). Once determined, presentation time was kept constant for each person throughout the experiment. For statistical analysis the data were averaged over all participants and over the two sessions. Thus, the varying presentation times were not critical. All other parameters were equal to those in Experiment 1.

3.2. Results and discussion

As in Experiment 1, hit rates and false alarms in condition ‘patch’ and condition ‘no patch’ are presented, but not interpreted further. The mean hit rates and the mean false alarm rates did not differ significantly between condition ‘patch’ and condition ‘no patch’ (hits, M (‘patch’) = 51.76; M (‘no patch’) = 43.13; $t(7) = 1.40$, n.s.; $g = 0.54$; false alarms, M (‘patch’) = 9.49; M (‘no patch’) = 6.56; $t(7) = 1.81$; n.s.; $g = 0.46$). The effect of varying distances (between target patch and task-irrelevant mask patch) was tested through hit rates, as in Experiment 1.

Figure 3 presents the mean percentage of hits in condition ‘patch’ as a function of distance, averaged over the target positions of $\pm 9^\circ$. An ANOVA for re-

Figure 3. Experiment 2: Hits (%) as a function of the distance (degrees of visual angle) between target patch and task-irrelevant patch. Bars show standard errors.

peated measures on the factor distance showed a significant effect of distance ($F(18, 126) = 17.82$, $p < 0.001$; $\eta p^2 = 0.72$), indicating that detection performance varied with distance. A trend analysis revealed a significant linear trend ($F(1, 7) = 34.39$, $p < 0.01$; $\eta p^2 = 0.83$), indicating a linear increase with increasing distance. A quadratic trend also was significant ($F(1, 7) = 57.24$, $p < 0.001$; $\eta p^2 = 0.89$), indicating that the performance reached a maximum, from which up performance did not increase further with further increasing distance. As in Experiment 1, detection performance increased linearly with increasing distances, and the effect of the task-irrelevant patch seemed to disappear with very large distances.

4. EXPERIMENT 3: REPLICATION WITH DIFFERENT TEXTURE AND MASK

Until now, exclusively orientation textures have been used. Experiment 3 was intended to prove the stability of our pattern of results, applying different and more difficult textures that had already been used in texture segmentation studies (Meinecke, 1989). Analogous to the data base of Experiment 2, a second large database was created comprising 19 target positions and 19 task-irrelevant patch positions from -9° up to $+9^\circ$ of visual angle (see Table 1).

4.1. Method

4.1.1. Participants. Eight participants (six female and two male) were paid to participate or received course credit. They were 20–25 years old, mean age was 22.6 years.

4.1.2. Stimuli. Context elements of the stimulus were circles (9 pixels in diameter) with a horizontal line in the middle (9×1 pixels), and the elements of the target patch were unfilled squares (9×9 pixels, see Fig. 4a). As in the previous experiments, a jitter randomly displaced the position of each texture element by zero, one or two pixels (in horizontal and/or vertical direction). The context elements of the mask were %-like figures, and the task-irrelevant patch elements of the mask were %-figures too, but rotated by 45° (see Fig. 4b). A jitter was imposed on the mask elements as well. The structure of both the stimuli and the masks were identical to those in Experiments 1 and 2. Analogous to Experiments 1 and 2, the pixel luminance of the rotated %-figures was increased to 3.3 cd/m^2 thus adjusting the impression of darkness of the irrelevant patch to that of the context elements.

4.1.3. Procedure. The procedure of Experiment 3 was identical to that of Experiment 2. The presentation duration was varied as in Experiments 1 and 2 (mean = 70.6 ms, min = 35.0 ms, max = 117.6 ms).

4.2. Results

As in Experiments 1 and 2, the hits and false alarms in the conditions ‘patch’ and ‘no patch’ were presented, but not discussed further. The hits and false alarms

Figure 4. Experiment 3: (a) Stimulus with target patch; (b) Mask with task-irrelevant patch. (a) and (b): The number of elements has been reduced for better visualization of the texture structure. For the same purpose the luminance contrast in this figure has been increased compared to the original stimuli.

Figure 5. Experiment 3: Hits (%) as a function of the distance (degrees of visual angle) between target patch and task-irrelevant patch. Bars show standard errors.

did not differ significantly (hits, M ('patch') = 57.40; M ('no patch') = 56.25; $t(7) = 0.37$; $p = 0.72$; $g = 0.09$; false alarms, M ('patch') = 6.93; M ('no patch') = 5.00; $t(7) = 1.32$; $p = 0.23$; $g = 0.68$). The effect of varying distances (between target patch and task-irrelevant mask 'patch') was tested through hit rates.

Figure 5 presents the mean percentage of hits in condition 'patch' as a function of distance, averaged over the target positions of $\pm 9^\circ$. An ANOVA for repeated measures on the factor distance showed a significant effect of distance ($F(18, 126) = 5.23$, $p < 0.001$; $\eta p^2 = 0.43$), indicating that detection performance varied with distance. A trend analysis revealed a significant linear trend ($F(1, 7) = 9.45$, $p < 0.05$; $\eta p^2 = 0.57$), indicating a linear performance increase with increasing distance. A quadratic trend also was significant ($F(1, 7) = 13.4$, $p < 0.01$; $\eta p^2 = 0.66$), indicating that the function of performance reached a maximum point from which up performance did not increase further with increasing distance. As in Experiments 1 and 2, detection performance increased proportionally with increasing distance until a maximum point. From this point up, performance seemed to asymptote as in the preceding experiments.

5. GENERAL DISCUSSION

The present texture segmentation study analyzed the influence of a task-irrelevant texture irregularity on target detection as a function of distance. In three experiments, we investigated the interaction between the target in the stimulus and a task-irrelevant texture patch in the backward mask. The central purpose was to find out

whether varying the spatial distance between the two texture irregularities modulates detection performance. The distance between the target and the task-irrelevant patch determined whether the task-irrelevant patch affected target detection or not and to what extent. As expected, all experiments revealed that performance was low with small distances, but increased proportionally with increasing distances. The performance increase reached a maximum at a large distance, from which up performance did not increase further with further increasing distance. The data concerning the general performance differences between the ‘patch’ and the ‘no patch’ condition are not discussed, because they must be interpreted cautiously. Due to the experimental design, one cannot exclude that the two texture irregularities have been confused by the observers, leading to an overestimation of the false alarm rate in the ‘patch’ condition and to an underestimation of hit rate in the ‘no patch’ condition.

In the following, we discuss our findings in terms of the *biased competition account* (e.g., Desimone, 1998). It is assumed that in the course of visual processing, multiple stimuli compete for perceptual representation. When a signal gains dominance of representation within one stage, it will tend to dominate on all subsequent processing stages. The competition can be biased in favor of a visual object and at the costs of the other competing objects by top down and by bottom up factors. Beck and Kastner (2008) derived six more specific predictions. One of these predictions implies that competition between multiple stimuli is strongest when their signals fall within the *same receptive field* (RF) of a neuron. Another prediction implies that competition can be biased from bottom up by the saliency of a visual object in favor of the *more salient* object and at the costs of the other competing stimuli.

It is assumed that the visual areas of the cortex are organized topographically (e.g., Desimone and Gross, 1979), and that one characteristic of the visual cortex is the increase of receptive field (RF) sizes at all successive stages of processing, as one moves from V1 to V2 to V4 and to TEO (e.g., Desimone and Duncan, 1995). As the (average) RF size on an early processing stage should be smaller than the RF size on a later processing stage, one may conclude that competition of two signals from close objects starts at an earlier processing level, than the signals from two distant objects, mediated by the RF size of the corresponding neural population. Kastner *et al.* (2001) provided physiological evidence (fMRI) that the spatial distance between four salient objects determined whether competition interactions occurred in V2, V4 or not. Whereas small separation was associated with competitive interactions in early visual areas with small RFs (V2, V4 and TEO), large separations induced competition in TEO (with large RFs), but not in V2 and V4. We assume that, if the distance between two salient locations in the stimuli is small, competition of their signals should start on an earlier stage of processing, where RFs are small than if distances are large. For the detection of a pop-out target, the representation of the target on a certain early stage of visual processing might be essential. Enlarging the distance between the two texture gradients should decrease the probability of competitive interactions on this processing stage. Moreover, the signal of the

task-irrelevant patch might have gained more saliency than the target signal, by differences in presentation time. Whereas the target was presented very briefly, the task-irrelevant patch remained until response. Thus, the competition between the two signals probably was biased in favor of the more salient task-irrelevant patch signal and at the costs of the less salient target signal. In the following, we distinguish three spatial relationships between the task-irrelevant patch and the target, and discuss our results in terms of the *biased competition account*.

- (1) Spatial overlapping of the target and the task-irrelevant patch. If the target and the task-irrelevant patch were overlapping, detection performance was at its lowest level. The probability should have been very high that the two signals competed for neural representation at a critical early stage of visual processing, where the RF size of the corresponding neural population is very small. Additionally, the task-irrelevant patch signal was probably more salient than the target signal. This more salient signal may have suppressed the target signal on an early stage of processing that might be crucial for target detection with high probability.
- (2) Medium distances between the two texture irregularities. If the task-irrelevant patch appeared within a certain distance to the target (*critical distance*), detection performance increased linearly with increasing distance. This observation fits to the finding in a form discrimination task (Mounts, 2000, Exp. 3). The spatial distance between the two texture irregularities might correspond to the probability with that the two signals fall into identical RFs on a critical early stage of processing. The impairing influence of the task-irrelevant patch was modulated by the distance only, if it appeared within a *critical distance*.
- (3) Large distances between the two texture irregularities. If the task-irrelevant patch appeared at very large distances from the target, detection performance was at its best. Additionally, if distances were large, performance did not increase further with increasing distance. In other words, if the task-irrelevant patch appeared outside of a *critical distance*, it seemed to have no more influence on target detection. This observation is in line with studies in visual search. In a form identification task, an irrelevant distracter impaired performance, if the distances were small. With large distances, form identification was not affected (Theeuwes *et al.*, 2004). It fits also to the finding by Mounts (2000, Exp. 2) that once the separation between the distracter and the target reached a certain distance, the distracter no longer influenced the target discrimination. The results of a subsequent texture segmentation study (Schade and Meinecke, in preparation) that involves the analysis of the entire databases (*cf.* Experiments 2 and 3) also fit well with the concept of a *critical distance*, showing a systematic variation with target eccentricity.

Very large distances between the texture irregularities should reduce the probability down to zero that the signals of the target and the task-irrelevant patch fall into identical (small) RFs on a critical processing stage. We conclude that the *critical*

distance might correspond to the average RF size on a cortical processing area that is critical for target detection.

In summary, our texture segmentation study shows that target detection can be affected by a task-irrelevant patch. The task-irrelevant patch did or did not modulate target detection, depending on whether it appeared inside of a *critical distance* to the target location or not. Within the *critical distance*, performance decrease was proportional to distance decrease. We interpret our pattern of results in the light of the *biased competition account* and propose that the *critical distance* corresponds to the average RF size on a cortical processing area that may be critical for target detection in texture segmentation tasks.

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