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CHANGE DETECTION IN CONTEXT

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Abstract

Although change detection constitutes an important and pervasive process in our everyday lives, phenomena such as change blindness show that we are quite limited in our ability to notice even large changes in visual scenes. Change detection is greatly dependant on attention deployment which can be influenced by the contextual setting in which a target item is presented. In this study we wanted to further address the influence of semantic relatedness of the changing item and the surrounding stimuli on the efficiency of change detection. The obtained results indicate that the contextual setting in which a changing element is presented influences the detection of changes. Change detection is generally more efficient in situations when changes are related to items incongruent with the surrounding context when compared to situations where an object belonging to the same category as surrounding items changes into another object from the same category.

Key words: change detection, contextual setting, semantic relatedness

INTRODUCTION

Change detection, a process of apprehending changes, constitutes an important and pervasive process in our everyday lives, so a reasonable assumption would be that we are generally good at this task. This conclusion would also correspond to our experience of a rich and vivid visual world and an intuitive notion of having detailed visual representations at all times. However, we are quite limited in our ability to notice even large changes in visual scenes, as can be seen from phenomena such as change blindness, our inability to detect changes in scenes from one glance to another (Simons & Levin, 1997). Different attempts have been made to explain how and why change blindness occurs (e.g. Simons, Chabris, Schnur & Levin, 2002; Rensink, 2000; Simons & Ambinder, 2005; Simons & Rensink, 2005) and according to one of the most plausible of these accounts, change blindness could reflect a failure to compare representations of pre- and post-change scenes (Simons, 2000).

Dependency of the change detection process on attention has been demonstrated in a number of studies which have shown that both bottom-up and top-down attentional biases are important for successful change detection. On the one hand, these studies show that changes are more easily noticed when they occur at a salient, clearly visible element of the scene (e.g. Scholl, 2000; Rensink, O'Regan & Clark, 1997), thus indicating the importance of bottom-up attentional bias. The importance of top-down attentional bias becomes visible from findings showing easier detection of changes related to elements rated as more interesting (Rensink, O'Regan & Clark, 1997), central to the meaning of the scene (Kelley, 2003) and personally or task relevant (e.g. Yaxley, & Zwaan, 2005; Jones, Jones, Smith Copley, 2003; Triesch, Ballard, Hayhoe & Sullivan, 2003).

Even though numerous findings emphasize the importance of attention in the change detection process, the relationship between these two is not symmetrical: attention is needed, but might not be sufficient, for the successful detection of changes (Williams & Simons, 2000). This conclusion is supported by studies showing that changes can go unnoticed even when they occur in attended objects (Simons, 2000) or if the subject is looking directly at the changed location (O'Regan, Deubel, Clark & Rensink, 2000). So, although attentional involvement may not by itself guarantee successful change detection, its' relevance can nevertheless be ignored. However, it is important to keep in mind that attention is a non-unitary phenomenon and can be influenced by different attributes, one of which is the context in which a stimulus is presented.

It has long been acknowledged that our experiences are defined not only by particular target objects that constitute the focus of our interest but also by the environment in which they are presented. When searching or trying to recognize objects around us we usually depend heavily on contextual information which influences processes such as object search or recognition (Biederman, 1981; Palmer, 1975; Bar, 2004). In an attempt to account for this influence, Chun (2000) states that contextual information is used to guide attention and the analysis of visual information. Auckland, Cave and Donnelly (2003) have shown that even a simple context, not necessarily a coherent scene, can influence object recognition and emphasized the importance of semantic relatedness of the context and target object for contextual facilitation. This context-object relation has been shown to be relevant in other perceptual processes, including change detection (Hollingworth & Henderson, 2000).

The present study was conducted in order to further address how semantic relatedness of the changing item to the surrounding stimuli influences the efficiency of change detection. Namely, we addressed the efficiency of change detection related to familiar objects presented not in a coherent scene, but a rather simple context, surrounded with objects which could belong to the same or a different semantic category. We expected more efficient change detection in situations when changes were related to items not belonging to the semantic category of the surrounding non-changing items (incongruent items) when compared to changes related to objects belonging to that category (congruent items). This hypothesis was based on the assumption that an item presented in an incongruent context would create a semantical "pop-out" or attract more attention from the perceivers and thus be perceived faster in comparison to items which are more similar to those surrounding them.

METHOD

Participants

There were 27 psychology students aged 19 to 22 years with normal or corrected vision who participated in the study and received credits for their participation.

Procedure

The experiment was designed using SuperLab and run on a PC computer. Participants were seated in front of the computer screen and presented with sets of stimuli used in a flicker paradigm. Viewing distance of 45 cm was maintained by a forehead rest. Before the beginning of each trial a fixation cross was presented and participants were instructed to press a marked key in order to begin the trial. Each stimulus trial included an alternating presentation of two stimulus pictures both lasting for 400 ms and separated by a 200 ms interstimulus interval. Each picture included a set of 10 images related to one of 5 particular categories of objects: vehicles, plants, toys, kitchen utensils or fruit. The images were all black and white sketches representing easily recognizable realistic objects of balanced size. The two alternating pictures in "change trials" differed in the identity of one of the images in the stimulus picture while in "no-change trials" there was no difference between the two pictures. No-change trials were used for controlling the accuracy of participants' reactions. The alterations of initial and changed stimuli were repeated 5 times, so that each trial contained the presentation of 10 individual pictures.

Five types of change-trials were presented to the participants throughout the experiment. They differed in the combination of the presented items in the set and the identity of the changed item, namely it's relation to the object categories of other items presented within the display. In four types of situations the non-changing items all belonged to the same category with the changing item either belonging to that (changing item congruent with non-changing items; e.g. an apple presented among fruit) or another object category (changing item incongruent with the non-changing items; e.g. an apple presented among vehicles). The fifth condition differed from the others and contained intermixed non-changing items from all categories. After the presentation of the initial display, the target items could change into

Table 1. Short descriptions and examples of each condition presented in the experiment

Condition	Description of condition	Example
Congruent-to-congruent condition	Change in an item congruent with the category of surrounding display items into a different item from the same object category	An apple surrounded by other types of fruit in the first picture changes into a banana in the second picture
Congruent-to-incongruent condition	Change in an item congruent with the category of surrounding display items into an item from a different object category	An apple surrounded by other types of fruit in the first picture changes into a car in the second picture
Incongruent-to-congruent condition	Change in an item incongruent with the category of surrounding display items into an item from the same object category	An apple surrounded by vehicles in the first picture changes into a truck in the second picture
Incongruent-to-incongruent condition	Change in an item incongruent with the category of surrounding display items into another incongruent item	An apple surrounded by plants in the first picture changes into a toy in the second picture
Mixed condition	Change in an item presented among intermixed items from all object categories	An apple surrounded by items from different categories in the first picture changes into a toy in the second picture

an item congruent or incongruent with the initial stimulus. Thus, change trials could belong to one of five change conditions which are presented in Table 1. Examples of stimulus displays from two conditions are presented in Figure 1.

Participants' task was to detect the change and quickly respond by pressing the marked keyboard key. If the trial contained no change participants were instructed not to respond until the end of the trial.

Overall 30 different trials were presented to the participants for each condition, amounting to a total of 150 trials presented in three series of measurement. Except for the mixed condition in which items of different categories were used as context for all trials, 30 trials in other conditions were distributed so that the items from each of five different categories were used as context in six trials. Different types of trials were presented quasi-randomly within each of the series and the order of the series was rotated between participants. Some of the pictures were repeated for different trials but each trial included a unique combination of the changing element and the surrounding context. Participants were given a practice period before the experiment. The training included a short block of trials equivalent to those presented in the main experiment. Overall, three trials per condition were presented in the training phase.

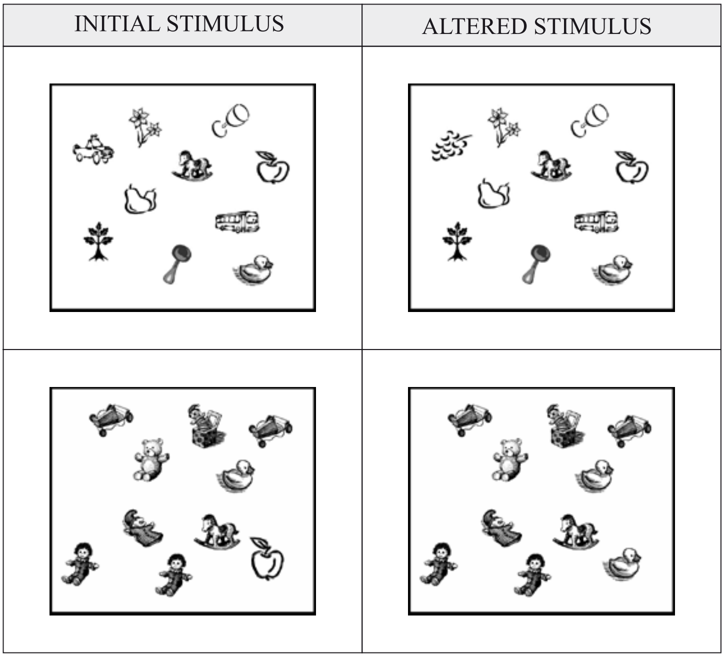

Figure 1. Two examples of stimulus displays used in the experiment. The initial and altered stimuli were presented in an alternating fashion within each trial (see Method). The task of the participants was to compare the two stimuli and press a response key as soon as they noticed a difference between the two stimuli. In the first row an example of a "mixed" condition is presented in which objects from different categories surround the item which differs between the two pictures. In the second row an example of an "incongruent-to-congruent" condition is presented in which an item initially incongruent with the context changes into a congruent one.

RESULTS

Accuracy and the timing of change detection expressed as the number of scene alterations were recorded. All participants had 95% or higher accuracy rates in no-change trials. Two dependant variables were used in order to compare the efficiency of change detection across different types of change trials: success and speed of change detection. Success of change detection referred to whether the participants noticed the change or not and was expressed as the proportion of correct detections (possible range: 0-1; higher number indicates better detection). Speed of change detection was operationalized as the timing of change detection in the trials where change was noticed and was expressed as the number of scene alterations necessary to notice the change (possible range: 2-10; lower number indicates faster detection). The success and speed of detection were significantly negatively correlated within all conditions except the "congruent-to-congruent" one ("congruent-to-incongruent" r = -0.64, p < 0.01; "incongruent-to-congruent" r = -0.47, p < 0.05; "incongruent-to-incongruent" r = -0.5, p < 0.05; "mixed" r = -0.77, p < 0.05). Stimuli related to different semantic categories within each condition were compared in order to check whether any differences were present among categories (e.g. whether changes would be more easily detectable when stimuli are presented in the context of e.g. fruit in comparison to plants). Since there were no significant differences between categories (p > 0.05), the results from all categories were combined within each trial type and analyzed as described below.

Success of change detection

The average percentage of perceived changes for each experimental situation was calculated in order to see if the efficiency of change detection differed across different experimental situations. All efficient change detection trials were combined regardless of the time needed to detect the change in the analysis which included ANOVA and paired t-tests. The obtained results are shown in Figure 2. ANOVA showed that the efficiency of change detection differed across experimental situations (F (4,104) = 4.09, p < 0.01, effect size: partial eta squared 0.14) so comparisons were made across pairs of experimental situations. Results of pairwise

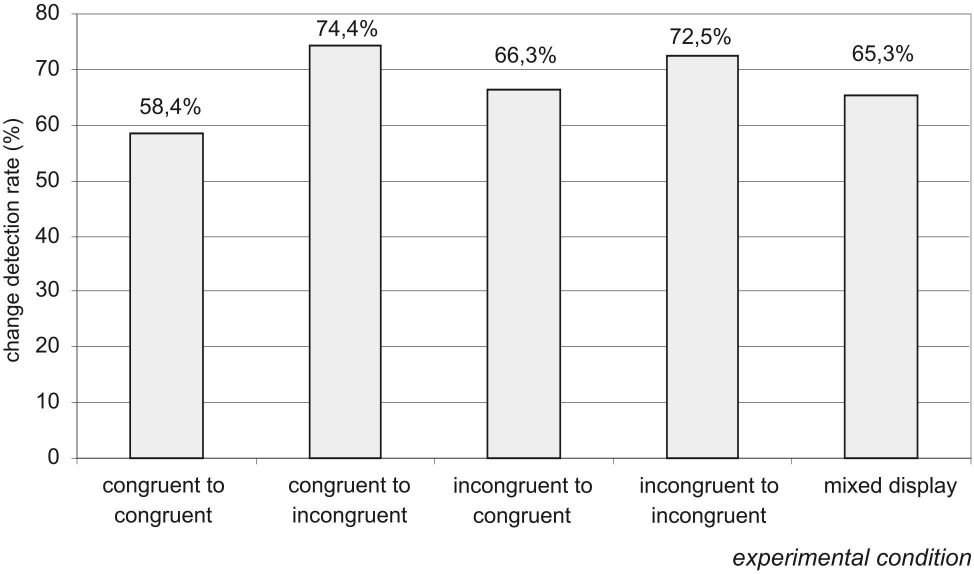

Figure 2. The efficiency of change detection (percentage of correct change detections) across different experimental conditions listed in Table 1.

comparisons indicate no differences between "incongruent-to-congruent", "congruent-to-incongruent", "incongruent-to-incongruent" and "mixed" conditions ($p > 0.05$). Change detection was less successful in "congruent-to-congruent" compared to "congruent-to-incongruent" ($t(26) = 3.8$, $p < 0.01$, effect size: Cohen's $d = 0.73$), "incongruent-to-congruent" ($t(26) = 2.1$, $p < 0.05$, effect size: Cohen's $d = 0.40$), "incongruent-to-incongruent" ($t(26) = 3.6$, $p < 0.01$, effect size: Cohen's $d = 0.69$) as well as the "incongruent-to-congruent" when compared to "congruent-to-incongruent" condition ($t(26) = 2.5$, $p < 0.05$, effect size: Cohen's $d = 0.48$).

Speed of change detection

We used the number of alterations of stimulus pictures before the change was noticed in order to test whether the speed of change detection differed among different experimental situations. Only the trials in which changes were successfully detected were used in the analysis which included ANOVA and paired t-tests. The obtained results are shown in Figure 3. ANOVA showed that the efficiency of change detection differed across experimental situations ($F(4,104) = 11.36$, $p < 0.01$, effect size: partial eta squared 0.29) so comparisons were made across pairs of experimental situations. This trend is somewhat similar to the results obtained in the comparison of success of change blindness, indicating slowest change detection in mutually similar "congruent-to-congruent" and "mixed" condition ($p > 0.05$). Change detection was significantly faster in "incongruent-to-incongruent" when compared to the mixed condition ($t(26) = 6.6$, $p < 0.01$, effect size: Cohen's $d = 1.28$) as well as "congruent-to-incongruent" ($t(26) = 2.4$, $p < 0.05$, effect size: Cohen's $d = 0.45$) and "congruent-to-congruent" condition ($t(26) = 3.7$, $p < 0.01$, effect size: Cohen's $d = 0.7$). Additionally, mixed display was significantly slower than "incongruent-to-congruent" ($t(26) = 5.6$, $p < 0.01$, effect size: Cohen's $d = 1.09$) and "congruent-to-incongruent" ($t(26) = 4.3$, $p < 0.01$, effect size: Cohen's $d = 0.82$) while "incongruent-to-congruent" was faster when compared to "congruent-to-congruent" condition ($t(26) = 2.9$, $p < 0.05$, effect size: Cohen's $d = 0.55$).

DISCUSSION

It has long been recognized that contextual setting and semantic relatedness of the target item to the surrounding stimuli can significantly influence perceptual and attentional processes. Hollingworth and Henderson (2000) have rendered change detection as one of them, showing that changes to semantically inconsistent (more informative) stimuli were more easily detectable than changes to non-informative parts of the scene. Austen and Enns (2000) have demonstrated another form of contextual dependency, showing that the efficiency of change detection depends not only on spatial locus, but also details of changing items. More specifically, their findings show that the critical element determining change detection efficiency seems to be the match between detail level of the change and the level-readiness or the expectations of the observer. Interestingly, contextual information in general is assumed to guide attention by creating expectations (Chun, 2000) and promoting the deployment of attention towards associated objects (Moores, Laiti & Chelazzi, 2003). Some authors mainly dismiss the idea of contextual facilitation, arguing that the results showing facilitation effects could actually reflect the response bias present in these experiments (Henderson & Hollingworth, 1999). However, Bar (2004) argues that, although relevant and often present, response bias still cannot account for the entire variance of results demonstrating context effects on different processes such as object search or recognition. Strong and clear evidence that information about the semantic relationship between objects and contextual settings affects perception of the scene even in brief presentations has also recently been presented by Davenport and Porter (2004).

Our results also contribute to growing evidence showing the importance of contextual influence on perception and attention. Unlike the majority of studies mentioned earlier, in which participants were presented with coherent holistic scenes, we created a rather simple contextual paradigm with realistic, familiar objects belonging to different categories in order to test if change detection efficiency would differ depending on whether the changing item belonged to the category of the surrounding items. Contrary to the object recognition process, we didn't expect the congruent context to facilitate change detection when an item belonging to the category of surrounding items would change into another object from the same category. Similar results were expected in the situation in which observers were presented with a mixed condition containing items from all categories and not creating any particular contextual setting. More efficient change detection was expected in the case where an incongruent item would change, especially if the altered stimulus would also represent an item from a category different than the prevailing one. Thus, we expected different effects depending on the characteristics of both the initial and altered changing stimulus.

The obtained results indicate that the change detection process can be influenced by context, namely semantic relatedness of the changing item with the remaining objects presented in the display. Changes of one item congruent with the non-changing objects into another item belonging to the same category were, in principle, detected less successfully and slowly when compared to most other conditions, except the mixed condition. Contrary to this, change detection was fast and efficient when changes were related to items incongruent with the category of non-changing items, especially when they changed into other incongruent items. This is mostly in accordance with results from Hollingworth and Henderson (2000) whose study included coherent scenes and different types of changes (addition/deletion and left/right orientation) as opposed to simpler context and identity changes used in this experiment. We also included a "mixed condition" in which non-changing items were unable to create a unison contextual setting, allowing us to establish a "baseline" detection rate and estimate the existence of interference and/or facilitation effects. Since change detection was similar in "congruent-to-congruent" and "mixed condition" we concluded that no interference effect was related to the former condition, so only facilitation effects on change detection in trials with incongruent conditions were present.

In interpreting their results, Hollingworth and Henderson (2000) proposed the *attentional attraction hypotheses,* suggesting that this trend of results is a consequence of more covert attention being drawn to the inconsistent objects whose processing requires more effort to reconcile their presence with the rest of the scene. It seems plausible to assume that the object that doesn't belong to the category of surrounding items (e.g. a vehicle presented among plants) could create a type of "semantical pop-out" in which it would be noticed faster. Since the probability of an incongruent object in the picture changing identity was 50%, during our experiment the participants could have also developed a strategy of attending to this element which would have aided their overall accuracy. Therefore, it seems plausible that the contextual effects obtained within the current experiment could be mediated by attentional effects.

On the other hand, congruent items don't stand out among other similar objects and are thus not likely to draw attention allowing easier change detection. Even if they are noticed, observers might be slower in detecting their change into another semantically similar object due to some type of "visual false memory", similar to the effect noticed by Miller and Gazzaniga (1998). This explanation could also be related to the *memory schema hypothesis* suggesting better long-term memory for inconsistent vs. consistent objects in the scene (Friedman, 1979; Hollingworth & Henderson, 2000). One factor that could account for some of the variance in this relation is eye movement which we were not able to control in this study. Although some of the results from Hollingworth and Henderson (2000) suggest that differences in the fixation pattern on the changing region can't entirely explain the inconsistent object change detection advantage, this matter could still be considered relevant, given some of the previous findings showing that objects inconsistent with a scene are fixated longer than consistent items (Henderson, Weeks & Hollingworth, 1999).

Another factor which could have influenced the obtained results was the nature of the design used. Namely, we used a within-subject experimental design in which all participants were presented with all experimental conditions. It is possible that their knowledge about different conditions could have had an influence on the obtained pattern of results and that some differences could emerge if a between-subject design was used. However, in the present experiment the within-subject design was used since it was hard to speculate how participants could systematically change their strategies in individual trials due to knowledge from different types of conditions.

When trying to interpret the obtained results, it seems rather plausible to return to Rensink (2002) who emphasizes the role of attention in constructing a limited number of comparisons of relatively complex structures that become the basis for change detection. The efficiency and speed of change detection depend on the priority of the changing object in the "activation map", a biased representation of the external world in which each element of the visual field is represented according to its' relevance and salience (Turrato & Mazza, 2004). Thus, changes can be noticed faster when they are associated with high priority items. Our belief is that the contextual setting in which a particular item is presented can influence this level of priority, modulate attentional deployment and, in a somewhat indirect manner, affect the change detection process.

CONCLUSION

The obtained results indicate that the contextual setting in which a changing element is presented influences the change detection process. Change detection is more efficient when changes are related to items not congruent with the surrounding, non-changing elements of the scene when compared to the situation when an object belonging to the same category with surrounding elements changes into another item from the same category.

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UTJECAJ KONTEKSTA NA PROCES OPAŽANJA PROMJENA

Sažetak

Iako smo u svakodnevnom životu okruženi podražajima koji se stalno mijenjaju i na koje uspješno reagiramo, fenomeni poput sljepoće za promjene pokazuju da je naša sposobnost efikasnog opažanja promjena zapravo poprilično ograničena. Uspješno opažanje promjena u velikoj mjeri ovisi o usmjerenosti opažača na podražaje koji se mijenjaju odnosno procesima pažnje koji su pod utjecajem konteksta u kojem se neki podražaj nalazi. U ovom istraživanju ispitali smo utjecaj semantičke povezanosti podražaja koji se mijenja i okoline koja ga okružuje na uspješnost opažanja promjena. Dobiveni rezultati pokazuju da kontekst prikazivanja podražaja utječe na učinkovitost i brzinu opažanja promjena. Naime, opažanje promjena je efikasnije u situacijama u kojima podražaj koji se mijenja nije semantički povezan s onima koji ga okružuju, na primjer ako je okružen podražajima koji pripadaju nekoj drugoj semantičkoj kategoriji. Nasuprot tome, promjene podražaja okruženog objektima iz iste kategorije teže se uočavaju, najvjerojatnije stoga što ti podražaji manje privlače pažnju opažača.

Ključne riječi: opažanje promjena, kontekst, semantička povezanost

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