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CHANGE BLINDNESS TO GRADUAL CHANGES IN FACIAL EXPRESSIONS

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Change blindness – our inability to detect changes in a stimulus – occurs even when the change takes place gradually, without disruption (Simons, Franconeri, & Reimer, 2000). Such gradual changes are more difficult to detect than changes that involve a disruption. In this experiment, we extend previous findings to the domain of facial expressions of emotions occurring in the context of a realistic scene. Even with changes occurring in central, highly relevant stimuli such as faces, gradual changes still produced high levels of change blindness: Detection rates were three times lower for gradual changes than for displays involving disruption, with only 15% of the observers perceiving the gradual change within a single trial. However, despite this high rate of change blindness, changes on faces were significantly better detected than colour changes occurring on non facial objects in the same scene.

Introduction

Change blindness, our inability to detect large changes in visual displays, is a striking phenomenon that has now been demonstrated through various paradigms (Rensink, 2002; Rensink, O'Regan, & Clark, 1997, 2000; Simons, 2000; Simons & Levin, 1998, 2003).

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While early empirical work in this domain is characterised by the use of highly artificial stimuli consisting of dot matrices (Philips, 1974) or letter arrays (Pashler, 1988), more recent demonstrations involve changes that occur in complex, realistic scenes (Rensink et al., 1997, 2000; Simons et al., 2000). Change blindness is a striking phenomenon because it challenges introspective judgments that our perception of the world is complete and accurate – a belief so strongly held that it has been dubbed "change blindness blindness" (Levin, Momen, Drivdahl, & Simons, 2000). For instance, in real life situations, observers fail to notice changes as dramatic as switching an individual with whom they are interacting to a different person (Levin & Simons, 1997). However, such demonstrations are easily dismissed as "mere magic", for observers do not expect the changes to occur and typically have their attention engaged elsewhere. Nevertheless, observers still exhibit change blindness even when directly instructed to detect changes. Numerous relevant studies have used the flicker paradigm, in which two images, identical to each other but for a single change, are displayed alternatively for 240 ms and separated from each other by a 80 ms blank screen – the disruption. This "flicker" sequence is typically looped until the observer detects the change. It can take many such loops (up to hundreds in some conditions) for the observers to become aware of the change. Rensink et al. (1997) have documented that detection rate is influenced by the location at which the change occurs. For instance, performance improves when the change involves an area of major interest, such as a face in a picture or any other stimulus that particularly attracts attention.

The stimuli used in flicker studies, however always involve a brief visual disruption, and hence the demonstration is again perhaps less compelling than it might first appear. One way to address this issue is to change the stimulus while the observer is making a saccade (Verfaillie & De Graef, 2001; Verfaillie, De Graef, Germeys, Gysen, & Van Eccelpoel, 2001), but here again the change occurs during a visual disruption (the saccade). "Gradual change" studies offer an alternative manner of implementing changes more naturally by introducing changes only very progressively, e.g., over a period of 12 seconds, thus without any disruption. Studies using this paradigm have explored people's ability to detect changes in object colour or changes involving the deletion or addition of an object. Simons et al. (2000) showed that gradual change produces very powerful change blindness despite the fact that the change is continuously happening in front of the observer. Moreover, they showed that in the case of colour changes, the level of change blindness was even higher for gradual changes than for disruption changes. For changes involving deletion or addition, change blindness rate was lower in gradual change conditions than in disruption conditions. However, this result might be due to artefacts. Indeed, such changes produce intermediate frames that necessarily contain easily noticed artefacts, such as transparent objects.

In this paper, we wanted to explore whether gradual change blindness can be induced by stimuli that are more complex than simple colour changes, while also addressing the limitations associated with the presence of the visual artefacts that inevitably occur when the changes consist in the addition or removal of objects. An interesting possibility is offered by facial expressions. Here, changes essentially involve modifications to the shape and spatial relationships of features that are internal to an object (i.e., a face). We surmised that change blindness might be induced by making such changes occur very slowly. However, because processing facial expression is such an important and automatised social skill, it might also be the case that changes in facial expression, even when they occur so slowly that they do not result in strong visual transients, might nevertheless be better detected than other changes.

In this respect, neuroimaging studies (Kanwisher, McDermott, & Chun, 1997; Puce, Allison, Asgari, Gore, & McCarthy, 1996), single cell recording (Perrett, Hietanen, Oram, & Benson, 1992) and patient studies (Farah, Levinson, & Klein, 1995) all suggest that faces selectively activate a particular area of the extrastriate cortex – the "Fusiform Face Area" (FFA). Note, however, that the issue of whether "faces are special" remains hotly debated, as other studies have also demonstrated activation of the FFA when car or bird experts are exposed to the stimuli for which they have acquired expertise (i.e., pictures of cars or of birds, respectively) (Gauthier, Skudlarski, Gore, & Anderson, 2000). Thus it seems difficult at this point to ascertain whether faces are "special" because of the involvement of innate cerebral regions dedicated to face processing or because we all share expertise in processing faces – an ability that involves fine visual discriminations for which an area such as FFA would be specialised (Gauthier, Anderson, Tarr, Skudlarski, & Gore, 1997; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 2000).

In the change blindness literature, it has been shown (using a flicker paradigm) that a single face presented among other objects (i.e., food, clothes, musical instruments, appliance and plants) was less prone to change blindness compared to these other objects (Ro, Russell, & Lavie, 2001). However, Palermo and Rhodes (2003) replicated this study and showed a superiority effect for a single object presented among several faces, that is an effect for the "odd-one-out" in the array, regardless of the significance of the stimuli. As a result, it remains unclear whether changes in faces are truly detected more efficiently than changes to non-face objects, or whether observed differences merely result from differences in saliency.

To summarise, whether faces are better processed than other objects in change blindness paradigms remains relatively unclear, but recall that our main interest in conducting this study was not so much to investigate change blindness to facial expressions per se, but rather to explore the extent to which gradual changes may fail to be detected when applied to complex stimuli in such a manner as to avoid the visual artefacts that occur when objects gradually appear or disappear.

Thus, in a novel application of the gradual change method, we asked whether observers would fail to detect gradual changes in the facial expressions of actors appearing in photographic, real-life scenes. We surmised that such gradual changes (in which every intermediate frame is plausible) might be attenuated for changes that occur on faces compared to changes that occur on other objects in the scene both because faces are usually important for humans (whether as a result of expertise or of innate biases) and because observers declared that these stimuli are in areas of particular interest in the scene (the second being probably a consequence of the first). In contrast to Simons et al. (2000), we used the very same scenes for colour changes and for facial expression changes (but they were of course shown to different groups of subjects). Finally, we also measured participants' confidence in their own performance so as to find out whether possible objective differences in the processing of faces are also accompanied by subjective differences.

Method

Subjects

85 undergraduate students from the Université Libre de Bruxelles participated either for partial class credit or for 2.5 euros. They were assigned to one of five conditions: transient 1 (n = 20), transient 2 (n = 20), flicker (n = 20), gradual change (n = 20) and scene description (n = 5).

Materials and procedure

Stimuli were displayed on a 17" 100 Hz CRT screen at a resolution of 1024 by 768 pixels. Subjects were tested individually and seated approximately 60cm from the screen. Each scene had a size of 756 by 567 pixels (subtending about 19° by 25° of visual angle) and was presented on a gray background. We used 8 different scenes composed of 3 actors (three different actors for each scene) showing various facial expressions and placed in different locations. We created two new versions out of each of these images:

one where the colour of an object was changed, and one where the facial expression of one of the three actors changed from a neutral to an emotional facial expression (4 positive and 4 negative) (see figure 1).

Colour change

We used Gimp 2 to artificially change the colour of one object (either an actor's garment or an object of the background) on each image.

Facial expression change

Both facial expressions were natural and were extracted from two different snapshots taken in the same conditions.

Changes of either type were approximately similar with respect to their respective size (Expression changes: minimum = 4.2% of the total image, maximum = 9.2%, mean = 6.4%; colour changes: minimum = 2.1%, maximum = 11.2%, mean = 7%), and were equally distributed to the right, left or middle part of the screen.

Scene description

We first conducted a pilot experiment in which five subjects were shown the 8 different pictures (the target character exhibiting a neutral expression) and were simply asked to verbally describe them in order to determine areas of interest (see Rensink et al., 1997). Inspection of subjects' responses clearly showed that faces and facial expressions were massively in the area of interest whilst other objects were in intermediate or marginal areas of interest (except for one object that was in the central area of interest).

Transient 1 (control condition)

In this condition, each pair of images A and B were presented consecutively (i.e., without any disruption). The first had a duration of 250 ms and the second remained on the screen for 11750 ms to obtain a 12s sequence. Subjects were instructed to "attend to a change that would occur suddenly in the image". They were also asked to locate the change through a mouse click, to verbally describe it, and to provide a subjective estimation of their confidence using a three-points scale (1 = 'saw', 2 = 'felt', 3 = 'guess'). Subjects were asked to guess in the event they had failed to perceive the change. The second image remained on the screen until subjects responded. Subjects were prompted to respond after 11750 ms had elapsed. The direction in which the change occurred (AB or BA) was counterbalanced across subjects. For colour changes, we used the picture in which the face of interest in the other condition showed a neutral expression. Before the test, the task was explained to subjects through a demonstration (involving an image that was

Figure 1.

a. Stimulus with original colour and target character showing a neutral expression; b. Modified stimulus with target character showing an emotional facial expression (circled); c. Modified stimulus with target object coloured differently (boxed).

not used during the main experiment) in which the location and the nature of the change (i.e., a glove appearing on someone's hand) were shown. During the test itself, each subject was shown 4 facial expression changes and 4 colour changes (the type of changes for a given scene being counterbalanced across subjects) presented in a random order with the constraint that 2 changes of the same type could not appear successively. Each trial was initiated by a key press from the subject, which was followed by a 1500 ms fixation cross. This condition was designed to match the one used by Simons et al. (2000). As in previous change blindness studies, the changes were detectable when presented without disruption. Indeed, results showed that 81% of the colour changes and 84% of the expression changes were correctly identified. There was no significant difference between these two conditions [$t(19) = -0.46$; $p = 0.649$].

Transient 2 (control condition)

This condition was exactly the same as the previous, except that the first image was presented for 6s instead of 250 ms. The second image was presented for 6s before the prompt appeared on the screen. This condition was designed to be as comparable as possible to our "gradual change" and "disruption" conditions. As in the "Transient 1" condition, changes were detectable when the first image was presented for a longer time. Under these conditions, subjects identified 85% of the colour changes and 84% of the expression changes. There was no significant difference between these two conditions [$t(19) = 0.21$; $p = 0.833$].

A comparison between the 2 control conditions indicated that there were no significant differences between them, as confirmed by an ANOVA applied on detection rate, with condition (Transient 1 vs. Transient 2) as a between-subjects factor and type of change (Expression vs. Colour) as a within-subjects factor (all Fs < 1).

Gradual change (GC)

We used the same images as in the two transient conditions. We used approximately the same method as Simons et al. (2000) to construct our movies. Using morphing software (Morph Man 2000), we created 144 intermediate frames for each AB pair and gathered them in a 12s long QuickTime movie. For each pair of images, we created two movies, one involving an A to B change, and the second involving a B to A change. Here again, the task itself and the appearance of the gradual changes were explained to subjects before the main experiment began. Each trial was initiated by a key press from the subject, followed by a 1500 ms fixation cross. Each movie was presented once (12s), and the last image remained on the screen until the observer's

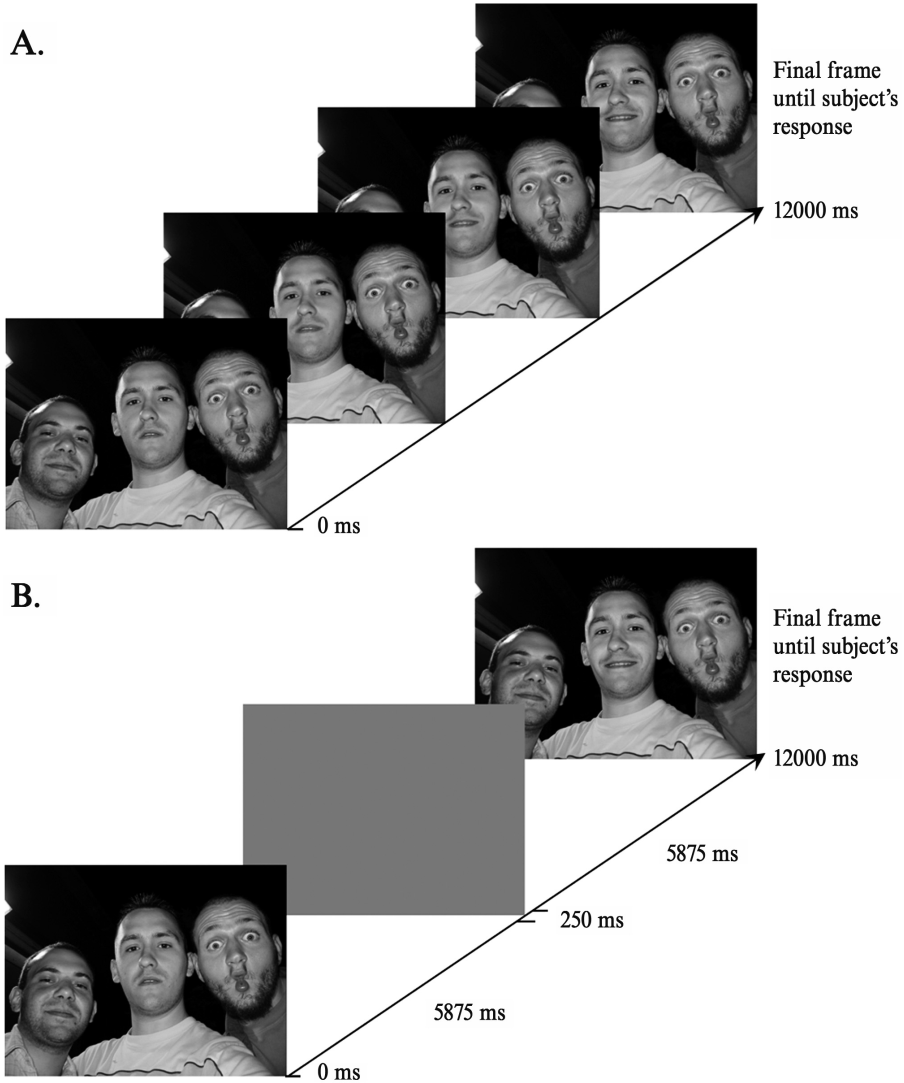

Figure 2.
a. Illustration of the procedure used in the gradual condition;
b. Illustration of the procedure used in the disruption condition.

response (see figure 2a). At the end of the 12s movie, a prompt reminded the subject to respond if no response had already been given. Subjects were explicitly instructed to look for a gradual change and to press a key as soon as they had detected it. The procedure was otherwise identical to that used in the transient conditions.

Disruption

We used the same scenes as in the previous conditions. Each stimulus was composed of two static images A and B (differing from each other only by an object's colour or by a character's facial expression).

The procedure was the same as in the transient conditions, except that each image A and B was presented for 5875 ms and that they were interrupted by a 250 ms grey coloured blank, so that the total sequence duration was again equal to 12s (see figure 2b). Contrary to previous conditions, subjects were instructed to look for a change that would appear after a short disruption. Their tasks were otherwise identical.

Results

Detection/identification rate

Recall that subjects were required to verbally describe the change, to express a confidence judgment, and to click on the changing area[1]. Comparing these measures shows that there are instances where subjects had expressed "guess" confidence ratings while nevertheless having correctly clicked on the changing area. We decided to consider all such cases as "guess" trials, since subjects had themselves categorised them so. It is indeed possible to correctly guess which region of a scene is likely to change even in the absence of any relevant phenomenology. All such trials (represented 8.5% of all trials) were subsequently removed from further analysis.

As a consequence, "correct identifications" were those trials for which the subjects (1) had been able describe the change (or at least the appropriate area[2]), (2) had clicked on the area containing the change and (3) had rated their confidence as "saw" or "felt".

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[1] As in Simons et al. (2000, footnote 3), the correct area was defined by a rectangle surrounding the maximal dimension of the change plus 35 pixels on each edge.

[2] We used a liberal criterion. For instance, if the observer designed the good character and said that "his head" was changing (instead of his expression) we considered that as a correct answer.

We conducted an ANOVA on detection rate, with condition (Gradual change vs. Disruption) as a between-subjects factor and type of change (Expression vs. Colour) as a within-subjects factor. This analysis revealed a significant effect of condition [$F(1, 38) = 19.37$; $p < 0.001$], detection rate being lower for the GC condition than for the disruption condition. We also found a significant effect of type of change [$F(1, 38) = 10.44$; $p < 0.002$], detection rate being higher for expression changes than for colour changes. The interaction was not significant [$F(1, 38) = 1.67$; $p = 0.204$] (see figure 3).

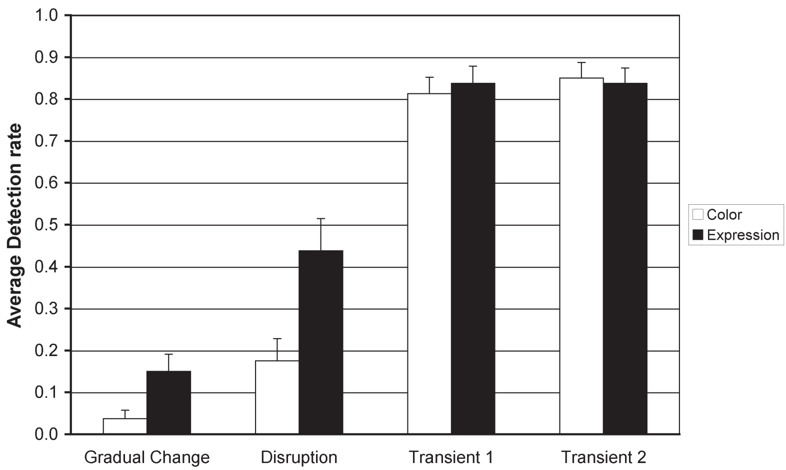

Figure 3.
Average change detection rate as a function of condition (Gradual change, Disruption, Transient 1 and 2) for each kind of change (Expression vs. Colour). Error bars represent s.e.m.

Confidence judgments

Recall that subjects had to rate their confidence using a three-points scale (1 = 'saw', 2 = 'felt', 3 = 'guess'). We also conducted the same ANOVA on subjects' confidence judgments and found a significant effect of condition [$F(1, 38) = 25.76$; $p < 0.001$], confidence being higher in the disruption condition than in the GC condition. Neither type of change [$F(1, 38) = 2.99$; $p = 0.091$] nor the interaction [$F(1, 38) = 2.99$; $p = 0.092$] were significant (see figure 4). We could not conduct ANOVAs involving confidence ratings and RTs on the detected changes only because the detection rate was too low.

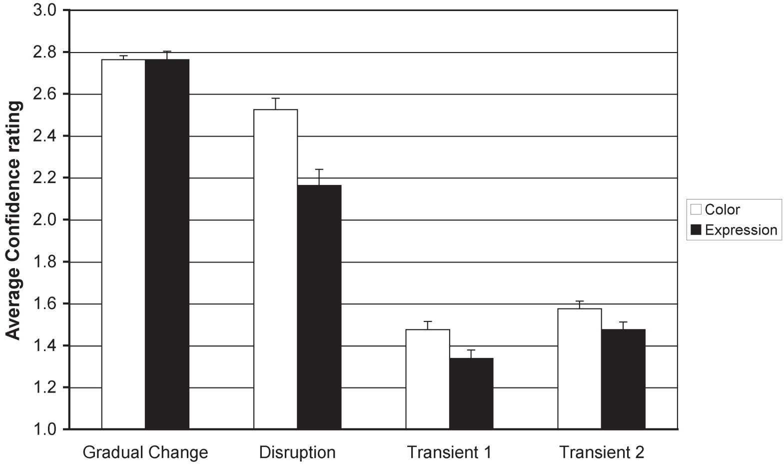

Figure 4.
Average confidence rating (1 = 'saw', 2 = 'felt', 3 = 'guess') as a function of condition (Gradual change, Disruption, Transient 1 and 2) for each kind of change (Expression vs. Colour). Error bars represent s.e.m.

An ANOVA applied on detection rate of expression changes with condition (Gradual change vs. Disruption) and valence (Positive vs. Negative) as within-subjects factors yielded an effect of condition [$F(1, 38) = 10.35$; $p < 0.002$] but no effect of emotional valence [$F(1, 38) = 0.05$; $p = 0.824$]. The interaction was marginally significant [$F(1, 38) = 4.06$; $p = 0.051$], negative expressions changes tending to be detected more efficiently in the disruption than in the GC condition, while the reverse trend was true for positive expression changes. However, planned comparisons failed to support this trend ($p>0.05$). Note that it is possible that some of these results would have been significant had our design incorporated more trials.

To ascertain whether subjects were still "blind" to the change after a few repetitions of the same change category, we analysed order effects. Each subject saw 4 colour changes and 4 expression changes. We binned the 1st and 2nd changes of each category as "early changes" and the 3rd and 4th changes of each category as "late changes" to increase statistical power. We then conducted an ANOVA on detection rate, with condition (Gradual change vs. Disruption) as a between-subjects factor and type of change (Expression vs. Colour) and repetition (Early vs. Late change) as within-subjects factors. As expected, we found the same main effects of type of change and condition, as described above. Additionally, we found a trend for a repetition effect

[$F(1, 38) = 3.78$; $p = 0.059$], detection rate tending to be higher for late changes than for early changes. No interaction was significant.

Discussion

Many studies have now documented how observers often fail to detect large changes in visual scenes, even when intentionally looking for such changes. Here, we set out to explore whether change blindness also occurs when the changes unfold without disruption, and on objects as complex as human faces. To address these issues, we roughly followed the gradual change methodology introduced by Simons et al. (2000), but applied it to an entirely novel domain – facial expressions. Nevertheless, our results indicate that only 15% of participants detect slow, gradual changes in the facial expression of actors, even when such changes occur in front of their eyes as they intentionally scrutinise the stimuli under instructions to detect any change. Note also that our study differs from previous ones in that we used changing stimuli that are larger than previous studies (6.7% of the total surface area of the image vs. 1.9%, for instance, in the case of the Simons et al. 2000 study).

A second result of our study is that gradual changes are more difficult to detect than disruption changes, regardless of whether the changes concern faces or colours: the latter elicited three times as many successful detections than the former. This result is probably the most compelling evidence so far showing that disruption or occlusion are not necessary for change blindness to occur. Gradual change blindness can occur even when the scene is changing right in front of fully informed and intentional observers. This suggests that changes will fail to reach conscious awareness if the visual signal produced by the change is too weak to attract attention. Importantly, the difference between gradual and disruption changes was also reflected through the subjective measures (i.e., confidence judgments) we collected, which made it possible to compare metacognitive judgments and objective responding in this paradigm. Here, we found that both reflected the same information: Subjects were both better at detecting disruption changes than gradual changes, as well as more confident in their own responses in the former rather than in the latter condition.

The fact that we obtained higher change blindness rate for gradual changes compared to disruption changes independently of the type of change (colour or facial expression) contrasts with previous results. More specifically, Simons et al. (2000) found that detection rate was higher for the addition or deletion of objects than for colour changes under gradual change conditions, whereas the reverse was true under disruption change conditions. The discrepancy is probably attributable to the occurrence of visual artefacts resulting from the progressive addition or deletion of objects in Simons et al. (2000). Thus our results in fact strengthen the argument that gradual changes are more difficult to detect than changes produced by a disruption.

A final result of this study is that changes in facial expression, despite eliciting such high rates of change blindness, nevertheless remained better detected than comparable colour changes presented in the same context. This result is congruent with the large literature suggesting that faces and facial expression are of particular importance to the visual system (e.g., Eastwood, Smilek, & Merikle, 2001, 2003; Farah, 1996; Farah et al., 1995; Fox, Lester, Russo, Bowles, Pichler, & Dutton, 2000; Kanwisher et al., 1997). While finding appropriate controls is very difficult for faces, it should be stressed that in our experiment, the detection of colour changes was equal to the detection of facial expression changes in both "transient" conditions. In addition, there was no significant difference between positive and negative facial expressions in our study, though there is some evidence in the literature that negative facial expressions are of particular interest for the visual system (Eastwood et al., 2001; Fox et al., 2000; Hansen & Hansen, 1988; Ohman, Lundqvist, & Esteves, 2001).

Whether such undetected changes are represented (for instance by visual memory update, as suggested by Hollingworth & Henderson, 2004), and whether they can influence subsequent processing, remains unclear but converging evidence suggest that it seems possible (Fernandez-Duque, Grossi, Thornton, & Neville, 2003; Fernandez-Duque & Thornton, 2000, 2003; Laloyaux, Destrebecqz, & Cleeremans, 2006; Mitroff, Simons, & Franconeri, 2002; Thornton & Fernandez-Duque, 2000, 2002). Gradual change might be a good paradigm through which to investigate potential covert change sensitivity, as there is a continuous visual signal that could be processed by the brain even if this signal fails to attract attention[3] (Laloyaux, Devue, Doyen, David, & Cleeremans, submitted). Finally, our application of the change blindness paradigm to facial expressions could also prove useful to study the relationships between conscious and unconscious processing of emotion.

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[3] We thank Dan Simons for this suggestion.

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