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Change blindness in the absence of a visual disruption

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Abstract. Findings from studies of visual memory and change detection have revealed a surprising inability to detect large changes to scenes from one view to the next ('change blindness'). When some form of disruption is introduced between an original and modified display, observers often fail to notice the change. This disruption can take many forms (eg an eye movement, a flashed blank screen, a blink, a cut in a motion picture, etc) with similar results. In all cases, the changes are sufficiently large that, were they to occur instantaneously, they would consistently be detected. Prior research on change blindness was predicated on the assumption that, in the absence of a visual disruption, the signal caused by the change would draw attention, leading to detection. In two experiments, we demonstrate that change blindness can occur even in the absence of a visual disruption. In one experiment, subjects actually detected more changes with a disruption than without one. When changes are sufficiently gradual, the visible change signal does not seem to draw attention, and large changes can go undetected. The findings are discussed in the context of metacognitive beliefs about change detection and the strategic decisions those beliefs entail.

1 Introduction

Findings from studies of visual memory and change detection have revealed a surprising inability to detect large changes to scenes from one view to the next (Simons and Levin 1997). This phenomenon, now known as 'change blindness', occurs both during intentional tasks in which observers actively search for changes (eg Rensink et al 1997) and during incidental tasks in which a change occurs unexpectedly (Levin and Simons 1997; Simons and Levin 1998; Simons and Mitroff, in press). Demonstrations of change blindness can be quite dramatic. For example, observers sometimes fail to notice when the central actor in a simple motion picture is replaced by a different person wearing different clothing (Levin and Simons 1997). In fact, they often do not notice when the person they are talking to is surreptitiously replaced by a different person (Simons and Levin 1998). Change blindness can even occur when observers are actively looking for changes (Grimes 1996; Henderson and Hollingworth 1999; McConkie and Currie 1996; Rensink et al 1997; Simons 1996)

In all existing demonstrations of change blindness, both incidental and intentional, the change occurs during some brief visual disruption (for reviews, see Simons 2000; Simons and Levin 1997). For example, saccade-contingent changes have been used to explore visual memory for photographs of natural scenes. In these experiments, observers view a scene and periodically, during a saccade, some element of the scene is changed (Grimes 1996; Henderson and Hollingworth 1999; McConkie and Currie 1996). Changes occurring during a fixation are readily detected, but changes that coincide with a saccade are rarely noticed. Presumably, the smear of visual information on the retina caused by the rapid movement of the eyes serves as a global transient that masks the specific transient caused by the change. Similarly, when an original and modified version of a scene are separated by an 80 – 100 ms blank interval, observers are often blind to large changes (Rensink et al 1997), suggesting that any visual disruption that masks the location of the change can induce change blindness.

Recent demonstrations of change blindness have used many different types of disruption to similar effect, including saccades (Grimes 1996; Henderson and Hollingworth 1999; McConkie and Currie 1996), blank screens (Blackmore et al 1995; Rensink 2000b; Rensink et al 1997; Simons 1996), blinks (O'Regan et al 2000), 'mudsplashes' (O'Regan et al 1999), motion picture cuts or pans (Levin and Simons 1997; Simons 1996), and the introduction of a physical occluder (Simons and Levin 1998). All published studies of change blindness essentially take the same form: an initial scene is presented, followed by a brief visual disruption, and then by the changed scene. A central assumption in the change-blindness literature is that such disruptions are needed to hide the transient that would be produced by the change in the absence of a disruption. In other words, without some disruption to draw attention, the signal produced by a change should exogenously draw attention, leading to successful detection. Here we explore the possibility that even in the absence of a visual disruption and in the presence of a change signal, observers still may not detect large changes to scenes.

Visual disruptions could produce change blindness for at least two reasons: (i) The flash could effectively mask the initial scene, thereby eliminating any visual representation of the details of the scene. Essentially, the visual disruption or the changed scene overwrites the original scene and change detection fails because nothing of the initial display remains to compare to the current display [for a discussion of this 'overwriting' hypothesis see Simons (2000)]. Accordingly, successful change detection would require an abstract representation of the initial scene that could be compared with the changed scene. Unless the abstraction happened to include the changed property, observers would be change blind. (ii) The flash could draw attention away from the transient produced by the change, thereby hindering localization of the change. This explanation is consistent with the idea that attention is often drawn to changes but, in the absence of a unique signal, the change can not exogenously draw attention.

A recent set of experiments using a variant of the flicker task (Rensink et al 1997) appears to support the second explanation (O'Regan et al 1999; Rensink et al 2000). Rather than disrupting the display with a blank screen, the change occurs at the same time as another set of shapes are flashed on the display. Essentially, the photograph is continuously visible, and the change occurs whenever these shapes appear on the screen. The appearance of the shapes is similar to the visual experience of having mud splash on the windshield of a car while driving. Critically, this 'mudsplash' does not mask the change itself. That is, the transient for the change is still visible in the display when the mudsplash occurs; if observers know where the change will occur, they can see it happen. Under these conditions, observers still show substantial change blindness, although they tend to need fewer alternations of the original and modified scene to find the changes than when the changes occur during a blank screen. This finding suggests that change blindness occurs when a visual transient draws attention away from the change signal—masking is not necessary to produce change blindness.

Although change detection is typically successful when the change occurs instantaneously (eg Rensink et al 1997), other types of changes may go undetected even in the absence of distraction. For example, extremely small changes may not produce a sufficient signal to draw attention. Similarly, extremely gradual changes (grass or hair growing) generally do not draw attention even if we might subsequently notice that a change has occurred. Natural cases of gradual changes do not provide a strong empirical test of this prediction—typically, such gradual changes do not occur in the absence of any other changes—but it is hard to imagine that extremely slow changes would be seen. In these cases, the rate of change is below the threshold for perception.

Most change-detection researchers assume that, if everything in a display is static with the exception of the change itself, the change will automatically draw attention—some distraction is needed to divert attention from the change signal. However, some changes may produce a change signal that is large enough to be seen but not large enough to draw attention. Here we explore this possibility by comparing the detection of changes occurring during a blank-screen disruption to the detection of the same changes when the change occurs gradually during a dissolve from the original to the modified scene. This gradual-change task is different from all previous studies of change detection in that the change is continuous rather than discrete. In all prior studies, observers viewed an initial scene at time 1 and a changed scene at time 2 and they were asked to report whether anything was different (or, in an incidental task, they were interviewed afterward to determine if they had noticed any changes). In our gradual-change task, observers viewed the scene throughout the change and they were actively trying to find what was changing. If a visual disruption is needed to draw attention away from the change in order to produce change blindness, then these gradual changes should be readily detected. If, however, it is possible to produce a perceptible change signal that does not draw attention, then, even in the absence of any other signals or transients, observers may fail to detect the changes. A finding of change blindness for gradual changes would suggest that visual disruptions are not needed for change blindness to occur.

2 Overview of experiments

In both experiments, participants intentionally searched for changes in computer-presented photographs of natural scenes. The photographs were all resized to 720×480 pixels (or, in the case of 7 images in experiment 1, to 640×480 pixels), and a modified version of each photograph was created with Adobe PhotoShop. These changes did not introduce any anomalies into the images; both the original and modified images were plausible, such that observers could not readily determine if an image was modified. In experiment 1, these changes involved an object in the scene either appearing or disappearing (ie being replaced by the appropriate scene background). Note that, by reversing the order of presentation of the original and modified images, an addition change could be converted to a deletion change and vice versa [see Mondy and Coltheart (2000) for other change blindness studies of object additions and deletions]. In experiment 2, an object or region in the scene was changed to a different color (see Aginsky and Tarr 2000).(1) For both experiments, changes occurred equally often in each of the four quadrants of the images.

2.1 *Preliminary control experiment: No blank screen*

In most change-detection research, the changes are large enough that they are readily visible when one image of a pair is instantaneously replaced by the other image. Under these conditions, the change produces a localizable transient that will be detected, provided that observers did not happen to blink or move their eyes at the instant of the change.

2.2 *Method*

Nine participants viewed all of the image pairs in two blocks, one with all of the addition/deletion pairs used in the analysis of experiment 1 (58 images)(2) and one with all of the color change pairs used in experiment 2 (64 images). The order of these blocks

(1) We use the term 'color' to describe these changes, but in reality they were often both color and brightness changes. Similarly, the addition/deletion changes also typically had some color change, and in both experiments, the magnitudes of the contrast and color changes were not precisely controlled. In the analysis, we consider the relationship between detectability and the magnitude of the change in terms of size, contrast, and color.

(2) Note that in this experiment we actually tested 60 addition/deletion images, but 2 were found to have subtle editing mistakes that were not identified until subsequent image analysis. These image pairs were not included in the data analysis of this control experiment or experiment 1.

was counterbalanced across subjects. The initial image was presented for 250 ms, followed immediately by the second image, which then remained on the screen until the subject identified the changed location with a mouse click.

2.3 *Results and discussion*

As in earlier studies of change blindness, the changes we used were detectable when the original and modified image were swapped instantaneously without a visual disruption. Under these conditions, observers readily detected 97% of addition/deletion changes and 92% of color changes.(3) Of the 58 addition/deletion pairs, 48 changes were missed by one or fewer observers and only 2 changes were missed by more than two observers. For the 64 color changes, 43 were missed by one or fewer observers and only 7 were missed by more than two observers.(4) Thus, most of these detection failures can likely be attributed to inadvertent blinks or saccades during some trials, and the changes were sufficiently large; changes are readily detected when they occur instantaneously.

3 Experiment 1: Object additions and deletions

3.1 *Method*

3.1.1 *Participants.* A total of thirty-five participants were allocated to the following conditions: gradual ($n = 11$), disruption ($n = 13$), and guessing ($n = 11$). They received either course credit or \$6.00 – \$7.00 for participating.

3.1.2 *Materials and procedures.* After the experiment was completed, 6 of the 64 addition/deletion image pairs were found to contain editing mistakes (either the image pair was accidentally presented without a change or one of the images had a slightly different size or color spectrum due to errors in compression and resizing). Data from these six image pairs were eliminated from all analyses. The remaining 58 pairs were approximately equally distributed with respect to the quadrant in which changes occurred.

3.1.3 *Gradual condition.* In the gradual condition, changes were presented as 12 s long QuickTime movies created by dissolving one image of a pair into the other. Two movies were created for each change pair, with one change in each direction (ie all addition movies had corresponding deletion movies). In each movie, a single object gradually faded into or out of the scene. The change occurred at a rate of 12 frames per second,

(3) To calculate the percentage of changes detected, we identified all of the pixels that differed from one member of a pair to the other. We first determined whether observers responded by clicking the mouse on one of these pixels (see method section). This measure of detection, however, is too conservative an estimate of successful change detection. Some changes involved narrow objects (eg a bar or chain-link fence), so even if subjects clicked on the changed object, they might not select the particular pixels that changed. Also, even if observers correctly localized the change, they might respond just outside the changed region simply owing to the imprecision of their mouse click. Such slight errors might be even more likely in cases of object deletion because observers would have to click on the location that had previously been occupied by an object but that was now no different from the surrounding background. To produce a more accurate estimate of successful change detection, we calculated the distance from the subject's response to the nearest changed pixel. If that difference was less than 35 pixels (which is equivalent to 0.98 cm or 1.35 deg of visual angle given an approximate viewing distance of 40 cm; 1 cm = 35.8 pixels = 1.38 deg), we inferred that they had detected a change. All of the analyses reported are based on this estimate of successful detection.

(4) For the addition/deletion pairs, 30 were detected by all observers, 18 were missed by one observer, 8 were missed by two observers, 1 was missed by three observers, and 1 was missed by four observers. For the color changes, 25 were detected by all observers, 18 were missed by one observer, 14 were missed by two observers, 5 were missed by three observers, 1 was missed by five observers, and 1 was missed by all nine observers. The 1 image missed by all nine observers had a particularly small contrast change (2%) and was relatively small in size (1.7% of the image), but had a relatively large color change (45.97 in $L^*u^*v^*$ space). We are currently exploring the intriguing possibility that instantaneous color changes may sometimes go undetected when the contrast change is minimal.

meaning that the discrete steps in the change were sufficiently small (144 frames over 12 seconds) that the change appeared to be smooth and continuous. Although these changes were sufficiently gradual that they did not produce a strong transient, when observers attended to the region of the change, they could detect a change signal (see figure 1; compressed versions of example movies can also be viewed at the following sites: http://www.wjh.harvard.edu/~viscog/lab/demos.html and http://www.perceptionweb.com/perc1000/simons.html; they are also archived on the annual CD-ROM dispatched with issue 12 of *Perception*).

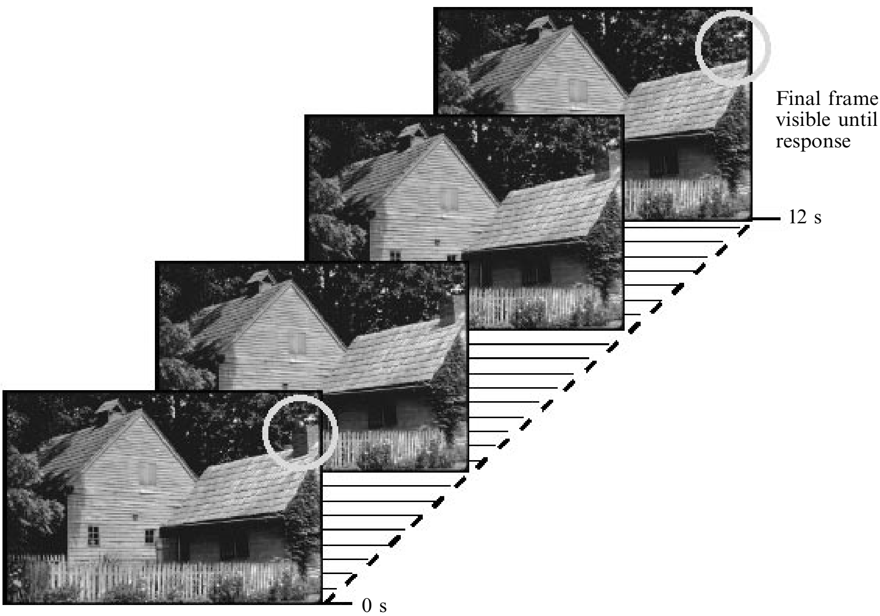

Figure 1. Illustration of the procedure used in the gradual condition. Over a 12 s period, the initial image dissolved into the changed image such that one object was gradually added/deleted from the scene or one object changed color. In the illustrated example, the chimney on the house (circled) gradually faded away. The final frame of the dissolve sequence remained visible until the subject responded.

Participants received instructions to search for the addition or deletion of an object. Prior to the test trials, observers viewed a single practice trial in which the quadrant of the change was identified in advance (in order to give them an opportunity to see an example of a change). Participants completed 64 randomly ordered test trials (32 addition and 32 deletion). Each image pair was viewed as an addition change by half the subjects and as a deletion change by the other half.

At the end of the movie, the final still frame remained visible until subjects responded. After 500 ms, observers were prompted to click the mouse on the changed region. This mouse click served as the primary dependent measure of change detection. After the mouse click, observers were then asked to report whether they (a) saw the change and were confident that they chose the correct location ('saw'), (b) they had no idea what had changed and selected arbitrarily ('guessed'), or (c) they thought they saw or felt something change, but were not certain ('felt'). This measure was included to gather preliminary data for other studies and will not be discussed here.

3.1.4 *Disruption condition.* The procedure for this condition was identical to that used in the gradual condition except that static images were used instead of movies. One image of a pair was presented for 11 250 ms, followed by a blank gray screen for 250 ms, then followed by the second image in the pair (with an object inserted or deleted). Again, 500 ms after the final image appeared, observers were prompted to click the mouse on the change. The second image remained on the screen until participants responded. In all other respects, the procedure was identical to that of the gradual condition (see figure 2). This condition is comparable to other blank-screen disruption experiments except that the initial image is presented for a longer duration (Simons 2000). The extended viewing was chosen to approximate the exposure provided by the gradual condition.

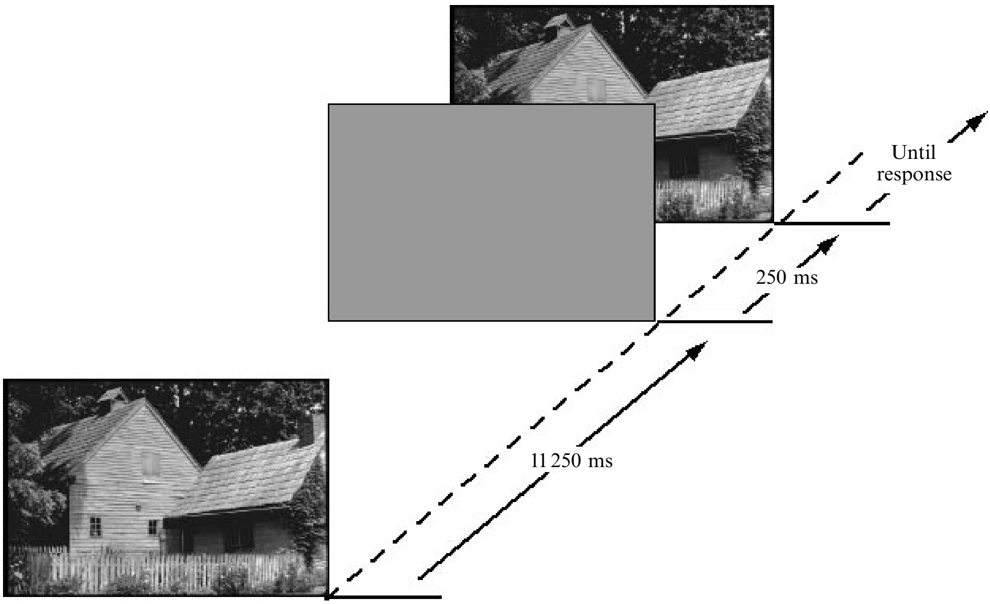

Figure 2. Illustration of the procedure used in the disruption condition. An initial image was shown for 11.25 s followed by a gray screen that was the same as the background gray behind the images for 250 ms. After the gray screen, the modified image appeared and remained visible until the subject responded.

3.1.5 *Guessing condition.* In the guessing condition, observers were shown one image in a pair, in this case the image with the changed object present. This condition was included to determine whether observers might have accurately detected changes simply by predicting the region that we were likely to change. In order to illustrate the types of changes we might make, 4 practice image pairs were presented side-by-side so that observers could compare the images directly. These practice images were not used during the experiment itself. After viewing the practice images, subjects were shown all of the test images and were asked to click the mouse on the object or region they thought we might delete (note that we could only show the image from each pair with an object present because subjects could not predict where we might add some unknown object).

3.1.6 *Coding.* The dependent measure in all three conditions was computed by determining the minimum Euclidean distance of the mouse-click response from the closest changed pixel in the image. Any response within 0.98 cm (35 pixels) of a changed pixel was counted as a successful detection (see footnote 3). To explore the effect of the size of the change on detection, the ratio of the size of the changed region relative to the total size of the image was calculated for each image pair. The size of the changed region ranged from 0.42% to 9.51% of the entire image (mean = 2.57%, SD = 1.89%). Several additional measures of change magnitude were also calculated for each image pair. First, we calculated the Michelson contrast of the changed area of each image. To do so, we compared the changed region with the region immediately surrounding the change; the minimal rectangle surrounding the change was expanded to include surrounding regions until the area surrounding the change occupied at least the same area within the rectangle as the change itself did. We then computed the difference in this contrast measure between the original and modified image, giving us the magnitude of the contrast change. Across images, the size of the contrast change ranged from 0.14% to 81.64% (mean = 20.58%, SD = 18.50%). We also computed the magnitude of the color change by converting the images from RGB to $L^*u^*v^*$ space (Wyszecki and Stiles 1982) and then computing the Euclidean distance in $L^*u^*v^*$ space for each changed pixel in the image pair (note: $L^*u^*v^*$ is a uniform color space such that equivalent Euclidean distances between points in the space correspond approximately to equivalent perceptual differences). These distances were then averaged for each image pair to give an estimate of the magnitude of the color change for that pair. Across images, the changes in color in $L^*u^*v^*$ ranged from 11.20 to 45.16 (mean = 26.13, SD = 6.68).

3.2 *Results*

Overall, observers detected approximately the same proportion of the changes in the gradual condition (mean = 64.3%, SD = 6.3%) and in the disruption condition (mean = 57.4%, SD = 11.5%); $F_{1,22} = 1.508$, $p = 0.232$. Averaging across these two conditions, change-detection performance was comparable for addition changes (57.8%, SD = 12.1%) and deletion changes (61.5%, SD = 9.7%); $F_{1,22} = 2.826$, $p = 0.107$. Change-detection performance for addition and deletion changes was comparable in the gradual (60.8% and 63.6% for addition and deletion, respectively) and disruption conditions (55.2% and 59.7%, respectively), as indicated by the lack of a reliable interaction: $F_{1,22} = 0.150$, $p = 0.7024$.

When observers incorrectly identified the location of the change, their average responses were relatively inaccurate (for the gradual condition: mean deviation = 7.23 cm, SD = 0.84 cm; for the disruption condition: mean deviation = 6.14 cm, SD = 0.67 cm). An item analysis suggested that the frequency with which a given change was detected in the gradual condition was significantly correlated with detection of the same change in the disruption condition ($r = 0.35$, $p < 0.01$).

In general, change detection was not reliably correlated with any of the measures of change magnitude. Prior to calculating each correlation, the distribution of the change magnitudes was trimmed by eliminating any image pair with a value more than 2 standard deviations away from the average value for that measure, along with an equal number of images from the other tail of the distribution. For both the gradual ($r = 0.16$) and the disruption ($r = -0.10$) conditions, size of the change was not significantly related to successful detection. Similarly, contrast and color change were not reliably correlated with detection in either condition (contrast: $r = 0.02$ for the gradual and $r = -0.11$ for the disruption condition; color: $r = -0.04$ for the gradual and $r = -0.17$ for the disruption condition). Together, these analyses suggest that the physical magnitude of the change is relatively unimportant in determining whether or not a change will be detected under these conditions.

The guessing condition was included to determine whether estimates of change detection were somewhat inflated by accurate guessing of what might change even in the absence of change detection. Participants successfully guessed the change location for 16.1% of the images on average (SD = 7.3%). When analyzed by stimulus pair, the proportion of subjects correctly guessing the change for a given image was not correlated with the accuracy of change localization in the gradual condition ($r = 0.03$) or in the disruption condition ($r = -0.05$). The ease with which observers could guess what might change did not appear to directly influence the likelihood that they would see the change in that image in either the gradual or disruption condition.

However, estimates of successful detection may be somewhat inflated by guessing the change.

3.3 *Discussion*

The results of this initial experiment suggest that, even when a change signal is present and there is no visual disruption, observers often fail to notice large changes to visual scenes. In fact, the rate of detection is not substantially better than when the initial and changed image are separated by a blank-screen disruption. These findings imply that a visual disruption is not needed in order to produce change blindness. In these gradual-change displays, the change occurred throughout the trial. However, when an object is gradually added to or deleted from a scene, at some points during the change, the object is partially transparent. This partially transparent object is anomalous—it is inconsistent with a photograph of a natural scene. It is surprising that subjects showed such a high degree of change blindness in spite of this inconsistency, and this inconsistency might help to account for the slightly higher rates of change detection for gradual changes than for changes across a disruption. The disruption and gradual conditions also may differ simply as a function of how the observer samples information from the scene. When the change is gradual, the magnitude of the change between any two sampling times would be smaller than the change in the disruption condition. Thus, if observers happened to sample the image just before and after a disruption, the amount of change would be larger than if they sampled the changing image at the same time points during a gradual change. This issue constrains comparisons of the absolute levels of performance in the two conditions.

To test the hypothesis that the inconsistency in the images during the gradual changes contributed to detection, in experiment 2 we used color changes rather than object additions and deletions. For gradual color changes, all of the intermediate states of the changed object are plausible. If observers were able to detect the anomaly during a gradual addition/deletion change, then for color changes the relative difference between the gradual and disruption conditions should be attenuated or reversed.

4 Experiment 2

4.1 *Method*

4.1.1 *Participants.* A total of thirty-six observers participated, with equal numbers ($n = 12$) assigned to the gradual, disruption, and guessing conditions. Data from one additional participant were excluded from analyses owing to a failure to follow instructions. Each participant received either course credit or \$6.00 – \$7.00 for participating.

4.1.2 *Materials and procedure.* Except where noted, the procedure and conditions were identical to those of experiment 1. A different set of 64 image pairs was used, with each pair containing one object or region which changed from one color to another. The size of the changed region ranged from 0.15% to 12.07% of the entire image (mean = 1.90%, SD = 1.83%). Thus, the changed regions were somewhat smaller than those of the addition/deletion set: $t_{120} = 1.75$, $p = 0.081$. The magnitude of the contrast change ranged from 0.46% to 64.38% (mean = 23.31, SD = 17.48), and was comparable to the average contrast change in experiment 1: $t_{120} = 0.81$, $p = 0.420$. The magnitude of the color change in $L^*u^*v^*$ ranged from 24.12 to 68.86 (mean = 40.51, SD = 8.34). Not surprisingly, the changes in color space were larger in experiment 2 than in experiment 1: $t_{120} = 10.44$, $p < 0.0001$. As noted earlier, most of these color changes were readily detected when the change was instantaneous with no disruption (see footnote 4).

4.2 *Results*

Consistent with the hypothesis that the anomalous intermediate state in the gradual addition/deletion trials might have differentially improved the detection of gradual changes, the detection of color changes (for which there is no anomalous state) was better in the disruption condition (mean = 41% detected, SD = 14%) than in the gradual condition (mean = 31% detected, SD = 8%): $t_{22} = 2.09$, $p = 0.049$. This pattern was the opposite of that found for addition/deletion changes, as revealed by a significant interaction between change type (addition/deletion versus color) and condition (gradual versus disruption): $F_{1,44} = 7.43$, $p = 0.009$ (see figure 3). Color changes were also detected less often overall than addition/deletion changes: $F_{1,44} = 65.54$, $p < 0.0001$. This difference could be attributed to the fact that the altered regions for the color changes were somewhat smaller in size on average than for the addition/deletion changes. Thus, the magnitude of the change signal might have been somewhat reduced for the color change relative to the addition/deletion changes. Alternatively, observers may have been able to code the presence or absence of an object more efficiently than its color. In a sense, the presence or absence of an object can be described by a single bit of information whereas color is more continuous. Consequently, observers may have an easier time retaining the features necessary to detect an object change. However, given that the object deletions and additions involved swapping an object with a heterogeneous background in a natural scene, it is not entirely clear that a single bit of stored information would suffice for detection. In general, comparisons of the absolute levels of detection for different types of change are relatively uninteresting, simply because they cannot be equated on all potentially relevant coding dimensions.

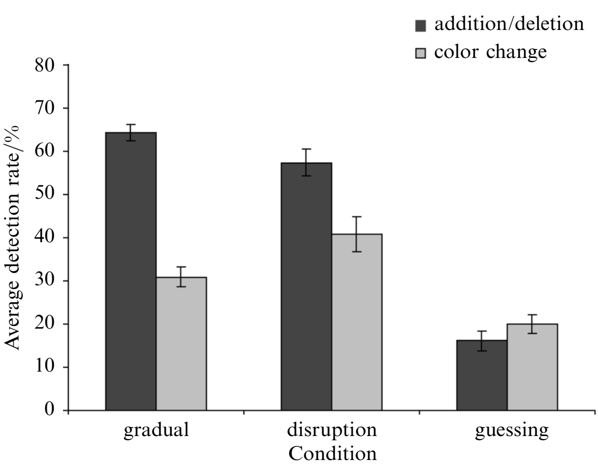

Figure 3. Average percentage of successfully detected changes for both types of change (color and addition/deletion) and all three experimental conditions (gradual, disruption, guessing). Error bars represent standard errors.

When observers incorrectly identified the location of the change, their responses were relatively inaccurate (for the gradual condition: mean deviation = 7.36 cm, SD = 0.70 cm; for the disruption condition: mean deviation = 6.94 cm, SD = 0.67 cm). An item analysis suggested that the frequency with which a given change was detected in the gradual condition was significantly correlated with detection of the same change in the disruption condition ($r = 0.60$, $p < 0.001$).

As in experiment 1, detection did not seem to be influenced by the magnitude of the change. The size of the changed region was not significantly correlated with detection for either the gradual condition ($r = -0.02$) or the disruption condition ($r = -0.02$). However, the magnitude of the contrast change was negatively correlated with detection, significantly so in the disruption condition ($r = -0.21$ for the gradual condition; $r = -0.34$, $p = 0.01$ for the disruption condition). This significant correlation is difficult to interpret in that it shows that smaller contrast changes were detected more readily. Color change magnitude was not reliably correlated with performance in the gradual condition ($r = -0.10$) or the disruption condition ($r = -0.18$).

In the guessing condition, participants correctly guessed the object that would change color for 20% (SD = 7.3%) of the images on average. Unlike the guessing in experiment 1, successful guessing of color changes was positively related to the likelihood of seeing a change (gradual condition: $r = 0.35$, $p < 0.01$; disruption condition: $r = 0.48$, $p < 0.001$); changes that were guessed more often were also detected more readily. This finding is consistent with the nature of the changes themselves. Relatively fewer objects in most of the scenes could plausibly change color and remain consistent with the scene at all times. Hence, guesses are more likely to be accurate. In contrast, for addition/deletion changes, most scenes would be consistent whether or not a given object is present, making guessing more difficult. Together, these findings suggest that detection rates in the color condition may have been inflated by guessing to a greater extent than detection rates for addition/deletion changes.

5 General discussion

These findings are consistent with claims in the literature that relatively little visual detail is represented and retained from one view to the next (O'Regan 1992; Rensink 2000a; Simons and Levin 1997). The findings also suggest that even during a single view of a scene, we do not perceive all the visual details. At least for the sorts of suprathreshold change signals generated by these gradual changes, attention is not automatically captured even in the absence of a disruption. Detection of gradual changes was far from perfect for both color and addition/deletion changes. Together, these findings suggest that a visual disruption is not necessary for change blindness to occur. Even in the absence of a visual disruption and in the presence of a suprathreshold change signal, observers often failed to notice large changes to photographs.

These experiments introduce an important new methodology for the study of change detection, and they represent the first study of the detection of truly dynamic changes to scenes. All previous studies explored the ability to compare an initial view with a modified view, yet gradual changes can be used to explore change detection in the absence of such an explicit comparison process. Gradual changes can be used to explore attentional effects on the detection of change signals and to explore the nature of the change signals themselves. By varying the rate and size of the changes, we can explore the threshold for successful detection [see Chaubrier and O'Regan (2000) for preliminary data on different rates of change]. This threshold is likely an attentional limitation because the changes in this study were visible if observers were attending to the correct feature or region. Further support for this claim comes from the finding that gradual color changes were detected less successfully than color changes that took place across a disruption. Even though the change was occurring throughout the viewing period in the gradual condition, observers were better able to detect color changes when they viewed the initial and modified scene separated by a visual disruption. This finding suggests that subjects might adopt different strategies when searching for gradual changes and when trying to find changes across a disruption. For gradual changes, subjects know that the change is occurring while they are viewing the scene. They might intuitively believe that any visible change will automatically draw their attention, leading to successful detection (see also Levin et al 2000). Hence, they may view the scene without trying to encode and retain the visual details. In contrast, with a disruption, observers know that they will have to remember the initial scene in order to detect the change. Hence, they may concentrate on encoding and remembering the visual details and consequently are somewhat better able to detect changes.[5] Although further studies are needed to explore this speculative metacognitive influence on different types of change-detection tasks, these studies suggest the possibility that strategic influences could affect the amount of information retained from one view to the next in intentional change-detection tasks. Gradual changes occur regularly in our environment, and many of them are simply too gradual to produce a perceptible change signal. Yet, even when they do produce a change signal when they are in full view, and when there are no visual disruptions or distractions, we may still fail to notice them.

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