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Spontaneous attention to people impairs change detection in natural scenes

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ABSTRACT

Faces capture attention, supporting key social processes, yet most research has examined them in isolation. This study investigated whether people (faces and bodies) capture attention in naturalistic contexts using a flicker change-detection paradigm. Participants viewed photographs of real-world scenes, with or without people, and identified changes between alternating images. Across three experiments, change detection was consistently impaired when people were present in the images, indicating that people may be drawing attention away from the surrounding environment. This effect was more prominent when people appeared infrequently (on 25% of trials), but weakened when they appeared frequently (on 75% of trials) and were irrelevant to the task. These findings suggest that people may be drawing attention spontaneously in complex visual scenes. This extends evidence of attentional biases for person stimuli and highlights the importance of task context in attentional processes.

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Face; attention; vision; perception; scenes

Introduction

Person-related stimuli, such as faces and bodies, can rapidly draw attention. This facilitates the perception of socially relevant information, including identity, gaze direction and emotional state. In visual search tasks, faces and bodies engage attention faster than other objects (e.g. vehicles, butterflies) or even animal faces (e.g. non-human primates). They are also preferentially fixated, even when task-irrelevant (e.g. during searches for non-social items) (Cerf et al., 2009; Crouzet et al., 2010; Langton et al., 2008; Little et al., 2021; Mayer et al., 2015; Simpson et al., 2014). These person stimuli also evoke specialised neural responses. The fusiform gyrus, the fusiform face area (FFA) and the N170 component – a neural response occurring about 170 milliseconds after stimulus onset – show enhanced activity primarily for faces, and somewhat for bodies (FBA: fusiform body area), compared to other visual stimuli (Bernard et al., 2018; De Lissa et al., 2019; Kanwisher & Yovel, 2006). These effects persist when faces and bodies are presented in the peripheral visual field (Bernard et al., 2018; De Lissa et al., 2019; Hietanen & Nummenmaa, 2011; Stekelenburg & de Gelder, 2004). Such evidence suggests that the human visual system is intrinsically biased to attend to people.

However, attentional prioritisation for faces and bodies depends on task demands and stimulus properties. For example, when the physical characteristics of face stimuli (e.g. luminance, contrast) are equated with non-face stimuli (e.g. houses) in a dot-probe task, the attentional bias disappears (Pereira et al., 2019, 2020). Furthermore, individual differences between faces can affect the allocation of attention, as attractive faces interfere more with attention switching in change detection tasks and draw more attention in spatial cuing tasks (Chen et al., 2012; Sui & Liu, 2009). The mode of presentation of person stimuli also affects processing. Many studies use simplified displays, such as visual search arrays with cropped faces embedded among a few non-face objects (e.g. Langton et al., 2008; Ro et al., 2007). In these settings, an attentional advantage for faces is typically found, but such stimuli lack the complexity of natural scenes, which vary in colour, luminance and context detail (Bindemann & Burton, 2009; Burton & Bindemann, 2009; Kelly et al., 2019; Nevard et al., 2025). In natural scenes, people also attract attention (Bindemann et al., 2010; Birmingham et al., 2009). Yet differences emerge compared to simplified displays. For example, variations in face views are equally detected in minimal displays, but in natural scenes, frontal faces are detected more effectively than profile views (Bindemann & Lewis, 2013; Nevard et al., 2023).

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Most prior research has examined attention to people under conditions where participants are explicitly instructed to search for faces (e.g. Bindemann & Lewis, 2013; Crouzet et al., 2010; Langton et al., 2008) or where task design made faces clearly relevant (e.g. Pereira et al., 2019, 2020; Sui & Liu, 2009). For example, the presence of attractive faces interferes with attentional allocation in a spatial cuing task, even though these faces are task-irrelevant (Sui & Liu, 2009). This type of paradigm can indicate the automatic, stimulus-driven allocation of attention to faces (Folk et al., 1992). However, the faces in such tasks are presented in prominent locations and therefore could still be viewed as relevant to an observer. This raises the question of whether people still draw attention in scenes when they are completely task-irrelevant. Eliciting spontaneous attention, in contrast to automatic allocation, would demonstrate that faces can attract attention without the explicit intent or task instruction (Pashler & Harris, 2001). Some studies have addressed this by comparing different instructions (such as searching for faces versus free viewing) and found that people attract attention regardless of these task demands (Birmingham et al., 2009). However, these stimuli often featured impoverished indoor backgrounds with people occupying prominent scene regions, limiting generalisability.

The present research investigates whether people draw attention in more complex scenes when they are irrelevant to the task. To test this, we employed the flicker paradigm, in which two alternating images differ by a single change while a blank mask interrupts direct comparison (Rensink, 2000; Rensink et al., 1997). Previous studies with simple visual displays, in which faces are embedded among a few objects, have shown that changes to faces are detected faster and more accurately than changes to other objects (Ro et al., 2001). This advantage disappears when faces are inverted, disrupting normal face processing (Davies & Hoffman, 2002; Goodrich & Yonelinas, 2020; Ro et al., 2001; Wang et al., 2014; Yang et al., 2009). However, results have been inconsistent, with some studies failing to replicate the effect (Palermo & Rhodes, 2003).

In the current study, we extend this method to naturalistic scenes. Photographs containing people were presented, but the change always occurred to an inanimate object within the scene. Participants were asked only to indicate whether a change occurred, ensuring that person stimuli were task-irrelevant. If change-detection performance declines when people are presented, even though they are unrelated to the task, this would provide further evidence that faces and bodies capture attention in complex visual environments.

Experiment 1

Experiment 1 tested whether people spontaneously draw participants' attention when presented within naturalistic scenes. A flicker task was used to assess whether the presence of people interfered with change detection. If people naturally draw attention spontaneously, performance should be impaired in person-present scenes compared to person-absent scenes.

Methods

Participants

Forty-seven undergraduates (4 male, 43 female) completed the experiment online. These participants ranged in age from 18 to 22 years, with a mean of 19.1 ($SD = .89$). Participants took part for course credit. All reported normal or corrected-to-normal vision. Ethical approval was granted at the University of Kent. All experiments in this study were carried out in accordance with the Declaration of Helsinki for experiments involving human participants. In all experiments participants provided informed consent to take part.

A power analysis using G*Power (repeated-measures ANOVA, within-between interaction, medium effect size $f = 0.25$, power = 0.95, $\alpha = 0.05$, 1 group, 4 measurements = 4) suggested a sample size of 36. This was adopted as the minimum sample size, and the study was advertised online for 3 weeks. The final sample represents all sign-ups during this period.

Stimuli

The stimuli consisted of 40 photographs taken around a university campus in daylight. All photos were taken outdoors and contained objects such as buildings, trees, traffic lights, and cars. Twenty photos contained people naturally occurring within the scene, varying in number (1 or 2 people), distance and viewpoint. The remaining 20 photographs contained no people in view. The images were sized to 1286 (w) × 965 (h) pixels at a resolution of 72ppi. Twenty photographs (10 person-present, 10 person-absent) were edited in Photoshop to remove a single object (e.g. signposts, footballs, trees, buildings, etc.). These serve as *change* trials. The remaining 20 photos were unaltered and flickered identically to create *no-change* trials. Thus, participants completed 40 trials in total, consisting of 10 person-present change, 10 person-present no-change, 10 person-absent change and 10 person-absent no-change. For an example, see Figure 1.

As we sought to create a stimulus set that captured people in natural settings, there was some variation in

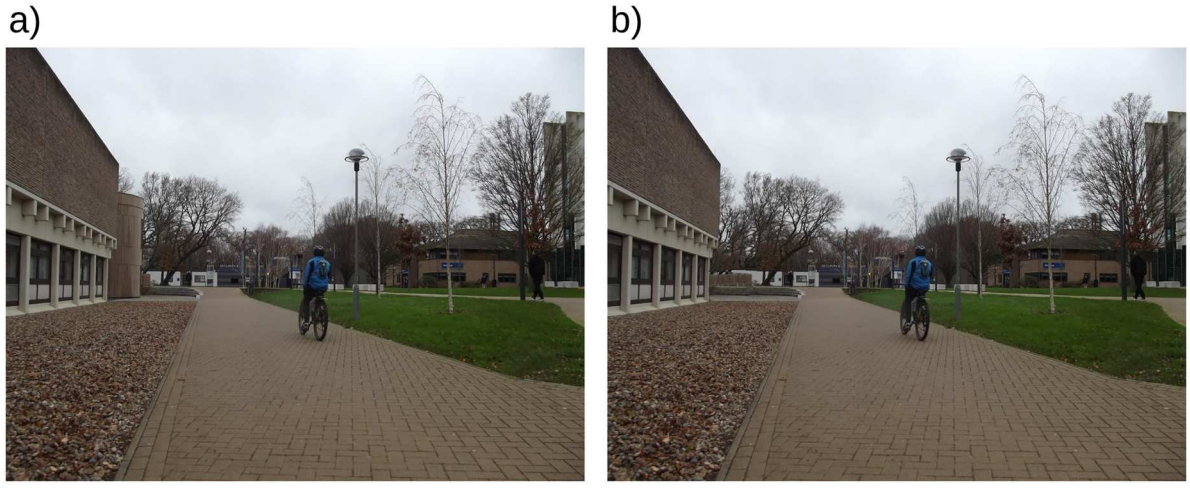


Figure 1. Example of a person-present change trial, (a) showing the original image without any changes and (b) the altered version with an object removed from the image.

person content across scenes. In total, 75% of the person-present images contained only one person, with 10% of images clearly containing two people. In addition, 15% of images were somewhat ambiguous with a main figure closer to the foreground and another person further away in the background. This person-content was balanced across the change and no-change conditions. There was also some variation in face view. In the change-present condition, 40% of images contained frontal-facing people, 30% of images showed people in profile, and 30% showed people facing away from the viewer. In the no-change present condition, 40% of people were shown in frontal view, 30% in profile, 30% facing away.

A person detection algorithm was also applied using MATLAB and the Computer Vision Toolbox to determine the proportion of the scene that the person present occupied in both the change and no-change condition. Bounding boxes were manually drawn around each person in MATLAB using a custom annotation script to determine the persons size and position. A 3×3 grid was applied to each image to determine person and object-change locations in the scenes (Figure 2). A similar approach was used to determine the size and position of the changes within the scenes, with the MATLAB script detecting the changes in pixels between the two paired images instead of manual selection. For the change person-absent condition, on average the changes covered approximately 1.60% of the total image, and 1.26% of the image for the change person-present condition. In comparison, people covered approximately 0.81% of the image in the change person-present condition.

In the change person-absent condition, along the horizontal plane, 20% of changes occurred in the mid-section and 80% in the outer section of each image. Along the vertical plane, 70% of changes were in the mid-section, with 10% in the lower, and 20% in the upper section. A similar pattern was observed in the change person present condition, with 20% of changes in the mid-section, and 80% in the outer section along the horizontal plane, and 70% of changes in the vertical mid-section and 30% in the lower section. Along the horizontal plane, 50% of people in the change person-present condition fell within the middle, and 50% in the outer areas, compared to 70% in the middle section and 30% in the outer sections in the no-change person-present condition. All people fell within the middle vertical plane for both change person-present and no-change person present trials.



Figure 2. An example of the 3×3 grid processed in MATLAB to determine where the person and the changes fell within the scene, as well as their size relative to the scene. The grid divides the image into middle and outer areas along the horizontal plane, and upper, middle and lower sections along the vertical plane.

To ensure that any differences in change detection performance between person-present and person-absent scenes could not be attributed to low-level visual differences between image sets, luminance, contrast, entropy, edge density, and mean spatial frequency were analysed for all images using MATLAB's Image Processing Toolbox. Independent samples t-tests revealed no significant differences between person-present and person-absent scenes on luminance $t(78) = 1.27$, $p = 0.21$, contrast $t(78) = 0.00$, $p = 1$, entropy $t(78) = 0.35$, $p = 0.72$, edge density $t(78) = 0.35$, $p = 0.73$, and mean spatial frequency $t(78) = 1.18$, $p = 0.24$. Similarly, no significant differences were found between change and no-change images on any of these measures, all $ps > 0.10$. This confirms that the image sets were well matched on low-level visual properties.

Procedure

Each trial began with a 1000 ms fixation cross, followed by the flicker display. Each trial cycled between the two images with a blank white display separating them to create a mask. Both images appeared for 500 ms, with the blank display appearing for 300 ms. This flicker cycled until the participant indicated whether a change occurred or not, by pressing one of two buttons on a computer keyboard. Participants were instructed to respond as quickly and accurately as possible. To avoid fatigue from flashing images, an interval screen followed each trial and lasted until the participant pressed the space bar to proceed. All 40 trials were completed in a randomised order.

Data analysis

To analyse performance, accuracy, reaction time (RT), and inverse efficiency scores (IES) were recorded for each trial. IES was calculated to consider the trade-off between accuracy and reaction times, by dividing reaction times by the proportion of correct responses. Thus, higher IES indicate less efficiency in detection when the proportion of errors is considered. Signal detection analyses were also conducted, with d' calculated using the loglinear correction for extreme values.

Results

The data for all experiments reported in this study can be accessed at https://osf.io/dn327/?view_only=0d425b2765894eea824d204ae254aa64. Thirteen participants were excluded from analysis due to accuracy scores more than two standard deviations below the sample mean (i.e. below 41.8% accuracy) or reaction times more than two standard deviations above the sample mean (i.e. above 12.85 s), leaving a final sample of 34. This exclusion rate may reflect the task's difficulty, which is considered further in the discussion section. For the remaining participants, the mean correct response times and percentage accuracy were calculated, as well as inverse efficiency scores (IES). These data are illustrated in Figure 3.

All three graphs depict a clear difference between the change and no change trials, which is expected due to participants being more likely to miss a change than falsely detect one. No difference was found between person presence for (a) reaction times, but observers were (b) less accurate and (c) less efficient in the person-present condition.

To examine the effects of change and person presence, the data were analysed with three 2 (change, no change) × 2 (person present, absent) repeated-measures ANOVAs. For response times, ANOVA revealed that participants were faster to respond to change trials ($M = 4.56$ s, $SD = 2.70$) than no-change trials ($M = 5.92$ s, $SD = 4.39$), $F(1,33) = 8.89$, $p = 0.005$, $\eta_p^2 = 0.21$, as search was completed once a change was found. This confirms that participants were adhering to task demands. However, ANOVA revealed no effect of person presence ($M = 5.53$ s, $SD = 4.04$) or absence ($M = 4.95$ s, $SD = 2.91$) on reaction times, $F(1,33) = 3.19$, $p = 0.08$, $\eta_p^2 = 0.09$, and no interaction between change and person presence, $F(1, 33) = 1.54$, $p = 0.22$, $\eta_p^2 = 0.04$.

For accuracy, ANOVA showed that participants were less accurate on change trials ($M = 30.3\%$, $SD = 14.5$) than no-change trials ($M = 81.2\%$, $SD = 16.2$), $F(1,33) = 113.15$, $p < 0.001$, $\eta_p^2 = .77$, due to being more likely to miss a change than falsely detect one. In addition, participants were more accurate on person-absent trials ($M = 58.4\%$, $SD = 7.56$) than person-present trials ($M = 53.1\%$, $SD = 9.54$), $F(1,33) = 7.58$, $p = .01$, $\eta_p^2 = .19$. No interaction was found between change and person presence, $F(1, 33) = 0.88$, $p = 0.36$, $\eta_p^2 = 0.03$.

Finally, inverse efficiency scores (IES) were calculated to consider the trade-off between accuracy and reaction times, by dividing reaction times by the proportion of correct responses (see Figure 2). Thus, higher IES indicate less efficiency in detection when the proportion of errors is taken into account. A repeated-measures ANOVA of these scores revealed less efficient processing in the change condition ($M = 21.78$ s, $SD = 16.30$) than no-change condition ($M = 7.15$ s, $SD = 4.66$), $F(1,33) = 27.49$, $p < 0.001$, $\eta_p^2 = 0.45$, and for person-present ($M = 16.83$ s, $SD = 13.79$) than person-absent trials ($M = 12.09$ s, $SD = 6.79$), $F(1,33) = 4.66$, $p = 0.04$, $\eta_p^2 = 0.12$. There was no interaction between change and person presence, $F(1,33) = 3.15$, $p = 0.09$, $\eta_p^2 = 0.09$.

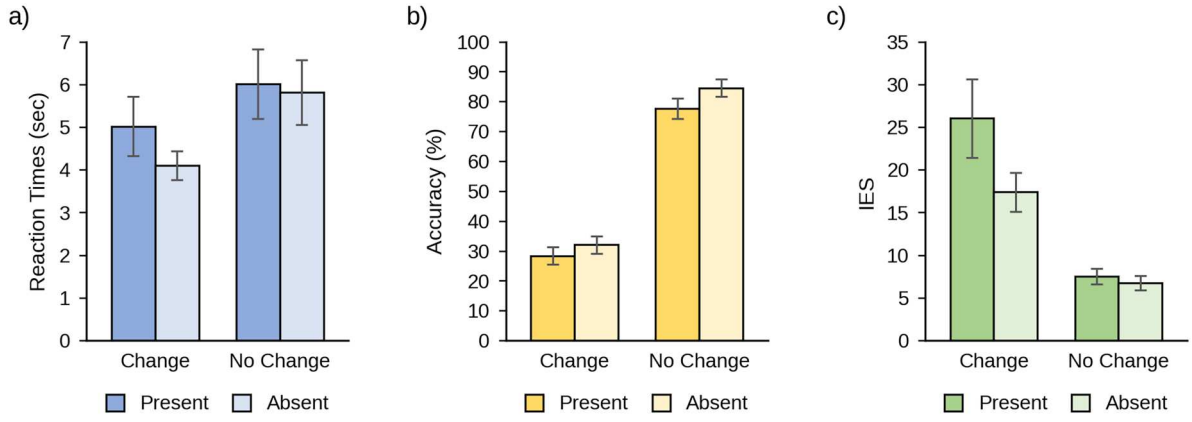


Figure 3. Mean reaction times, accuracy, and IES for person-present and person-absent scenes in the change and no change conditions.

Note: Error bars represent +/− 1 SE of the mean.

To reveal if participants were sensitive to person presence and to detecting the changes, *d'* was also calculated. A paired samples t-test revealed participants were more sensitive to no changes ($M = 2.08$, $SD = 1.28$) than changes ($M = -1.07$, $SD = 0.81$), $t(33) = 9.60$, $p < 0.001$. An additional paired samples t-test revealed that participants were less sensitive to changes when a person was present in the scene ($M = .33$, $SD = .33$) than when absent ($M = 0.68$, $SD = 0.55$), $t(33) = 2.50$, $p = 0.02$.

Discussion

Experiment 1 revealed no effect of person presence on reaction times, likely reflecting the time-constrained nature of the task, where at least one flicker cycle must be viewed before responding, and a full flicker cycle must be viewed before making a decision. However, accuracy was reduced when a person was present within a scene, and this effect was reinforced by IES and *d'*, which showed lower efficiency and sensitivity for person-present trials. Together, these findings suggest that people embedded in naturalistic scenes spontaneously draw attention and disrupt change detection, even when irrelevant to the task.

These conclusions are tempered, however, by low overall performance in this experiment, which suggests considerable task difficulty. Therefore, we examined trial-level accuracy to explore which stimuli produced the lowest detection rates. Of the 10 most difficult trials, six reflected change-present and four change-absent trials, with the former trials more difficult (mean 24.9%) than the latter (mean 29.4%). This is in line with the observations that changes were more likely to be missed when a person was present. To explore whether trial difficulty could be attributed to low-level image properties, we also examined correlations between item accuracy and image analysis of luminance, contrast, entropy, edge density, and spatial frequency values. No correlations were found between any low-level measure and trial accuracy, nor did hard and easy trials differ on any of these image properties. This suggests that variability in change detection performance across trials was not driven by low-level visual differences between stimuli.

A qualitative inspection of individual trial stimuli revealed a potentially important distinction between change-absent and change-present conditions. In change-absent trials, low accuracy appeared to reflect general scene complexity and the subtlety of the changing element. In change-present trials, however, changes were frequently located in regions of the scene more spatially distal from the person present. This pattern suggests that spontaneous attentional capture by the person may have directed observers' attention away from the location of the change, thereby compounding the difficulty introduced by the change's inherent subtlety. These observations are necessarily speculative given the small number of trials per condition, but provide preliminary qualitative support for the interpretation that person-presence captures attention spontaneously, impairing change detection for non-social elements in the scene.

Experiment 2

Experiment 1 demonstrates that people in scenes reduced change detection accuracy, but overall performance was low and close to chance, raising concerns about reliability. Experiment 2, therefore, aimed to replicate the effect using a simplified version of the task. To make changes more salient, the original images were

cropped so that the altered objects appeared larger and easier to detect. If the findings of Experiment 1 are robust, a decline in change detection should again be observed in person-present compared to person-absent scenes.

Methods

Participants, stimuli and procedure

Forty participants (14 male, 26 female) were recruited via the online platform Prolific and received payment for participation. These participants ranged in age from 18 to 39 years, with a mean of 25.8 ($SD = 6.24$). All reported normal or corrected-to-normal vision.

The stimuli and procedure matched Experiment 1, with one modification. The same photographs were used, but each one was cropped to remove some of the irrelevant background, making the critical change larger and more salient (see Figure 4). This adjustment was intended to increase accuracy by reducing search demands. Cropping varied depending on the change location, and all images were resized to match the dimensions used previously. All changes now covered a larger proportion of the overall images, covering approximately 2% of the images in the change person-absent and person-present conditions.

Results

Five participants were excluded from the analysis due to accuracy scores more than two standard deviations below the sample mean (i.e. below 36.9%), leaving a final sample of thirty-five participants. To determine whether accuracy improved from Experiment 1 to Experiment 2, an overall accuracy score was calculated based on performance across all conditions for each experiment. An independent t-test on these data revealed that accuracy increased between Experiment 1 ($M = 55.7\%$, $SD = 6.53$) and Experiment 2 ($M = 66.4\%$, $SD = 12.37$), $t(67) = 4.44$, $p < 0.001$, $d = 1.07$, confirming that cropping successfully reduced task difficulty.

All three graphs depict a clear difference between the change and no change trials, which is expected to be due to participants being more likely to miss a change than falsely detect one. No difference was found between person presence for (a) reaction times or (c) IES, but observers were (b) less accurate in detecting changes.

The mean correct response times, accuracy and IES data were then calculated for all conditions of Experiment 2. These data are illustrated in Figure 5. To examine the effects of change and person presence, the data were analysed with three 2 (change, no-change) × 2 (person present, absent) repeated-measures ANOVAs. For response time, ANOVA revealed faster reaction times for change ($M = 5.62$ s, $SD = 2.52$) than no-change trials ($M = 9.20$ s, $SD = 6.20$), $F(1,34) = 17.94$, $p < 0.001$, $\eta_p^2 = 0.35$. However, there was no difference in response times between person-present ($M = 7.57$ ms, $SD = 4.20$) and person-absent trials ($M = 7.26$ ms, $SD = 4.01$), $F(1, 34) = 1.21$, $p = 0.28$, $\eta_p^2 = 0.03$, and no interaction between factors, $F(1, 34) = 0.25$, $p = 0.62$, $\eta_p^2 = 0.01$.

For accuracy, ANOVA showed that participants were less accurate on change ($M = 43.4\%$, $SD = 18.9$) than no-change trials ($M = 89.3\%$, $SD = 13.8$), $F(1, 34) = 151.90$, $p < 0.001$, $\eta_p^2 = 0.82$, while responses were also less accurate on person-present ($M = 63.6\%$, $SD = 15.1$) than person-absent trials ($M = 69.1\%$, $SD = 12.3$), $F(1, 34) = 7.26$, $p = 0.01$, $\eta_p^2 = 0.18$. No interaction was found between change and person presence, $F(1, 34) = 0.48$, $p = 0.49$, $\eta_p^2 = 0.01$.

Finally, an ANOVA of IES also revealed less efficient responses in the change ($M = 18.13$, $SD = 14.49$) than the no-change condition ($M = 10.14$, $SD = 6.02$), $F(1, 34) = 7.86$, $p = 0.008$, $\eta_p^2 = .19$. However, there was no difference in efficiency for person-present ($M = 15.30$, $SD = 8.18$) and person-absent trials ($M = 12.98$, $SD = 11.62$), $F(1, 34) = 0.97$, $p = 0.33$, $\eta_p^2 = 0.03$, and no interaction between change and person-presence, $F(1, 34) = 0.47$, $p = 0.50$, $\eta_p^2 = 0.01$.

To reveal if participants were sensitive to person presence and to detecting the changes, *d'* was also calculated. A paired samples t-test revealed participants were more sensitive to no changes ($M = 2.83$, $SD = 1.26$) than changes ($M = -0.35$, $SD = 1.06$), $t(34) = 13.00$, $p < 0.001$. An additional paired samples t-test revealed participants were less sensitive to changes when a person was present in the scene ($M = 1.06$, $SD = 1.04$) than when absent ($M = 1.42$, $SD = 0.92$), $t(34) = 2.70$, $p = 0.01$.

Discussion

Experiment 2 replicated the key finding of Experiment 1. Change detection was less accurate and less sensitive to detecting changes when people were present in scenes, even though they were task-irrelevant. As in Experiment 1, this effect was not observed in response times, likely reflecting the temporal constraints of the flicker paradigm. Yet Experiment 2 found no effect of people on the inverse efficiency scores, which combine speed and accuracy measures.

Together, the findings from Experiments 1 and 2 suggest that people in naturalistic scenes capture

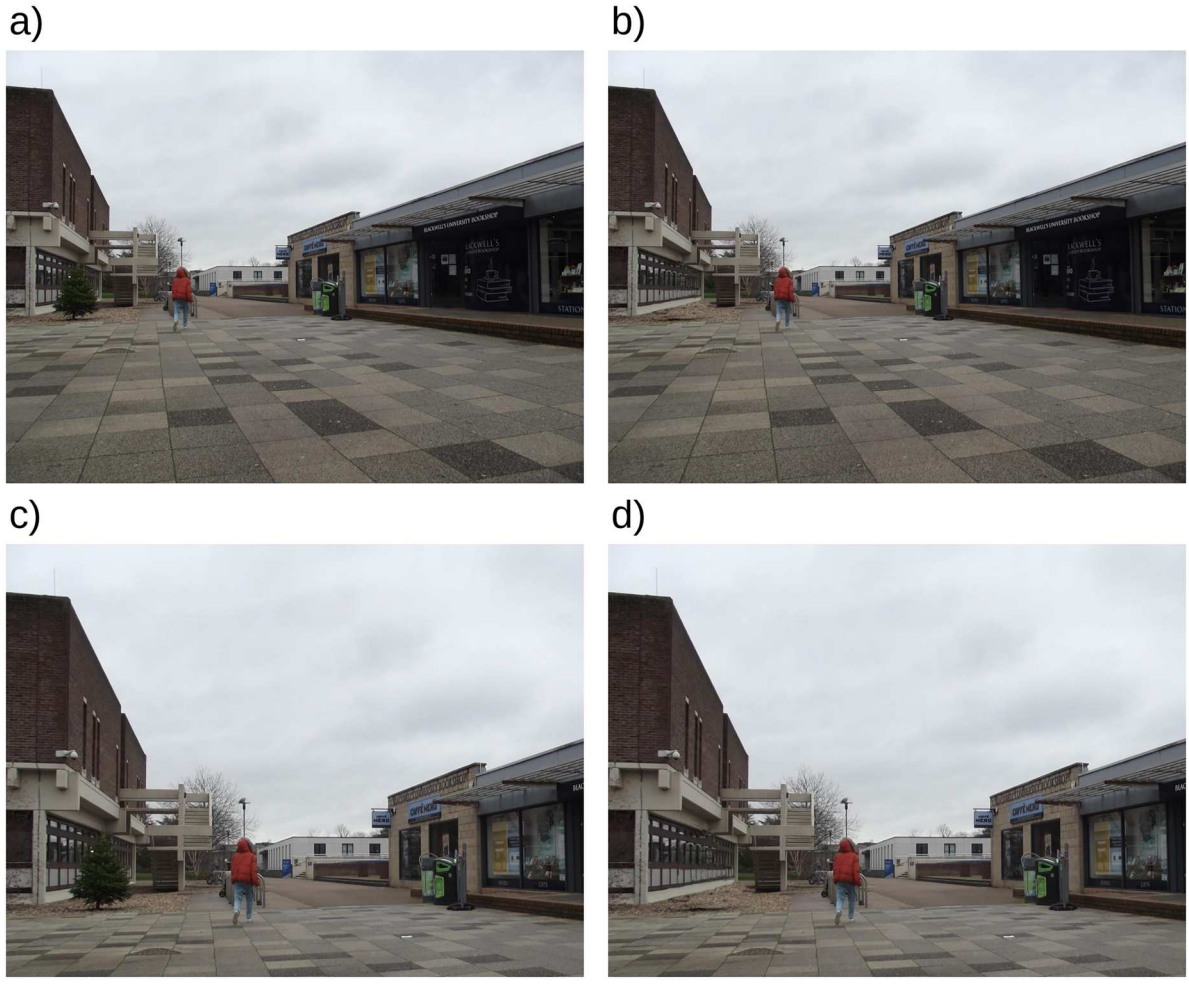


Figure 4. Example of the cropped stimuli, with (a) the original image unedited image from Experiment 1, (b) the edited image from Experiment 1, (c) the cropped version of the unedited image used in Experiment 2, and (d) the cropped version of the edited image in Experiment 2.

attention and interfere with the detection of unrelated changes. However, in both experiments, people appeared in 50% of trials. This frequency may have encouraged participants to treat people as task-relevant, since higher prevalence increases the likelihood of detecting a target, while low-prevalence targets are often missed (Beanland et al., 2016; Biggs et al., 2014; Godwin et al., 2015; Menneer et al., 2010; Wolfe et al., 2007). To address this, Experiment 3 systematically manipulated the prevalence of people to provide a stronger test of whether they draw attention when task-irrelevant.

Experiment 3

Experiment 3 manipulated the frequency of person presence to examine whether task relevance interacts with person prevalence in guiding attention. In visual search, low-prevalence targets are more likely to be missed (Beanland et al., 2016; Biggs et al., 2014; Godwin et al., 2015; Menneer et al., 2010; Wolfe et al., 2007). The relatively high frequency of person presence in the previous experiments, where people appeared in 50% of trials, might therefore account for their consistent attentional draw (Biggs et al., 2014). To test this, three versions of the task were created, with person presence set to 25%, 50% or 75% of the trials. If prevalence moderates attentional capture, interference in detecting changes should increase when people appear frequently (75%) and decrease when they appear rarely (25%).

To improve comparability of conditions, the stimulus set was also updated. In Experiments 1 and 2, people varied unsystematically in orientation, face view and distance from the camera, which can influence detection (see, e.g. Bindemann & Burton, 2009; Bindemann & Lewis, 2013; Burton & Bindemann, 2009; Or & Wilson, 2010). In Experiment 3, all people were depicted facing forward with a clear frontal face view.

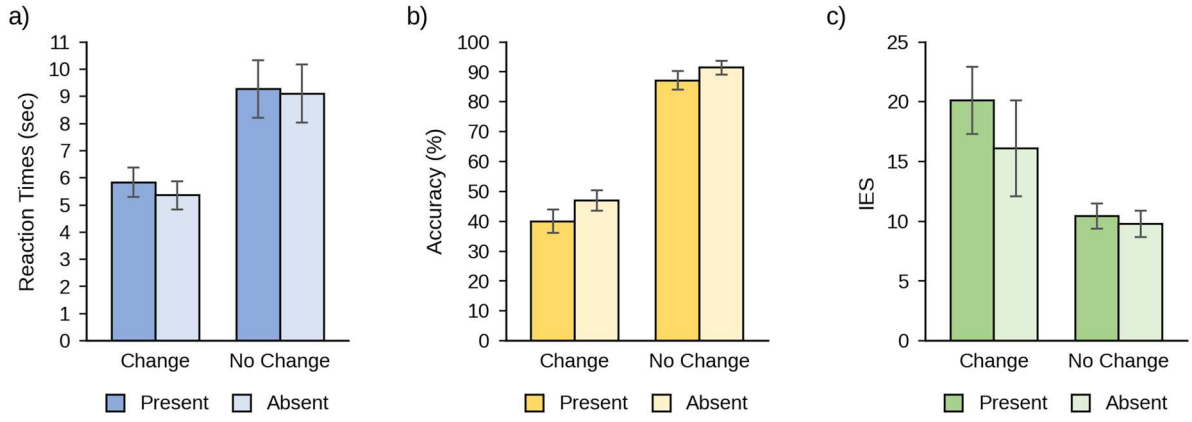


Figure 5. Mean reaction times, accuracy, and IES for person-present and person-absent scenes in the change and no change conditions.

Note: Error bars represent +/− 1 SE of the mean.

Method

Participants

One hundred fifty-two undergraduates participated in a between-subjects design (42 in the 25% prevalence condition, 61 in the 50% condition, 49 in the 75% condition). Variation in sample size occurred due to the number of sign-ups that were achieved once the study was advertised online. One hundred twenty-four of the participants were female, twenty-four were male, and four were non-binary, with an age range of 18–38 years ($M = 19.55$, $SD = 2.88$). Participants took part for course credit. All indicated normal or corrected-to-normal vision.

Stimuli and procedure

A new set of 160 photographs were taken around a university campus. In half of these (N = 80), one person would appear systematically facing forward in the scenes in a frontal view. The remaining 80 photos contained no people. All images measured 1286 (w) × 965 (h) pixels at a resolution of 72ppi. Each image was edited in Photoshop so that an object (e.g. signposts, football, trees, buildings, etc.) was removed, creating the change condition. Example stimuli are displayed in Figure 6.

In the experiment, each prevalence condition consisted of 80 trials, but the proportion of person-present trials varied. In the 25% condition, 20 trials contained a person within the scenes, comprising 10 trials in the change condition and 10 trials in the no-change condition. The remaining 60 trials did not contain a person (30 change, 30 no-change). The 50% condition contained an equal number of person-present and person-absent trials. Forty trials contained a person (20 change, 20 no-change), and 40 trials did not (20 change, 20 no-change). For the 75% condition, 60 out of the 80 trials were person-present (30 change, 30 no-

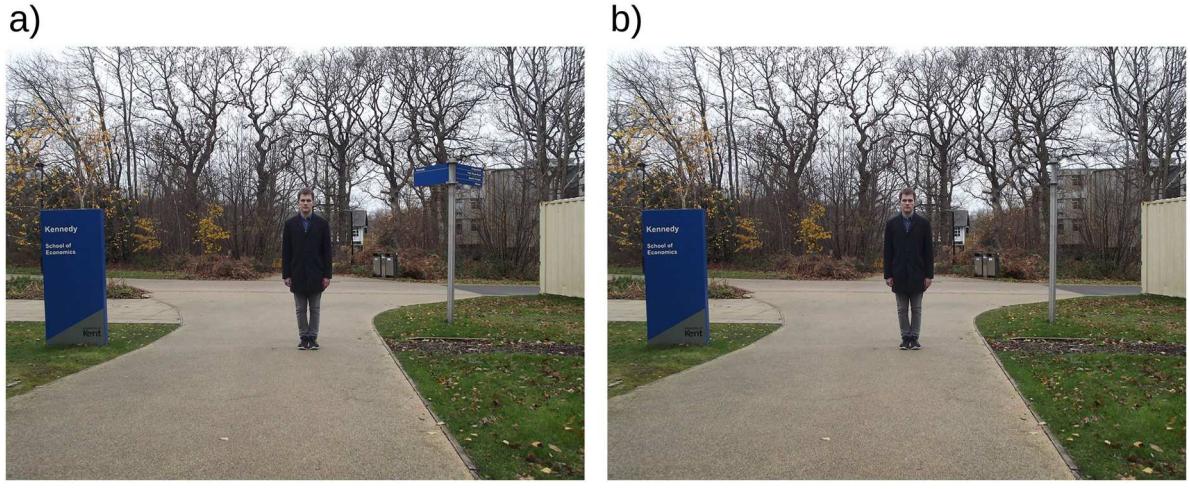


Figure 6. Example of person-present change stimuli for Experiment 3, with (a) the original image and (b) the altered version.

change), with the remaining 20 trials person-absent (10 change, 10 no-change). The trial procedure for this experiment was identical to that used in the preceding experiments.

To control for low-level visual properties, scenes were photographed both with and without a person present, using identical camera position, angle, and lighting conditions. Each scene therefore served as its own control, with the experiment fully counterbalanced in all three prevalence conditions. This ensured that any differences in change detection between person-present and person-absent conditions cannot be attributed to differences in luminance, contrast, spatial frequency, visual clutter, or change magnitude between image sets. Due to this counterbalancing, change sizes were also equivalent across person-present and person-absent conditions in this experiment. These are summarised in Table 1.

As in the preceding experiments, a person detection algorithm was applied using MATLAB and the Computer Vision Toolbox to determine the proportion of the scene that the person present occupied in both the change and no-change condition, for all three prevalence types. Bounding boxes were manually drawn around each person in MATLAB using a custom annotation script to determine the persons size and position. A summary of results is presented in Table 1. A similar technique was also applied to detect the size of the changes in each condition and their placement (see Table 1).

Results

Thirteen participants (four in the 25% condition, six in the 50% condition and three in the 75% condition) were excluded from analysis due to accuracy scores more than two standard deviations below the sample mean (i.e. scoring below 43.3% accuracy in the 25% condition, 56.7% in the 50% condition, and 40.9% in the 75% condition) or reaction times that fell more than two standard deviations above the sample mean (i.e. responses above 8.48 s in the 25% condition, 12.59 s in the 50% condition, 7.87 s in the 75% condition), leaving a final sample of one hundred thirty-nine. The mean correct response times and percentage accuracy were calculated for the remaining participants.

Pooled analysis

In the first step of the analysis, the data from all prevalence conditions were pooled to examine the overall effect of person presence on change detection. A 2 (change, no-change) × 2 (person present, absent) repeated-measures ANOVA was conducted for accuracy, response times and IES for the whole dataset. These data are shown in Figure 7.

For response times, ANOVA revealed that participants were faster to respond to change ($M = 3.29$ s, $SD = 1.26$) than no-change trials ($M = 6.29$ s, $SD = 3.78$), $F(1, 138) = 139.74$, $p < 0.001$, $\eta_p^2 = 0.50$, as search was completed once a change was found. ANOVA also revealed slower reaction times when a person was present in the scene ($M = 4.92$ s, $SD = 2.47$) compared to their absence ($M = 4.65$ s, $SD = 2.37$), $F(1, 138) = 13.34$, $p < 0.001$, $\eta_p^2 = 0.09$. No interaction between change and person presence was found, $F(1, 138) = 1.65$, $p = 0.20$, $\eta_p^2 = 0.01$.

All three graphs depict a clear difference between the change and no change trials, which is expected to due to participants being more likely to miss a change than falsely detect one. Observers were (a) slower to respond, (b) less accurate, and (c) less efficient for person-present trials than for person-absent trials.

For accuracy, ANOVA revealed that participants were less accurate on change trials ($M = 55.7\%$, $SD = 15.4$) than on no-change trials ($M = 93.9\%$, $SD = 12.0$), $F(1, 138) = 685.28$, $p < 0.001$, $\eta_p^2 = 0.83$, due to being more likely to miss a change than falsely detecting one. In addition, participants were more accurate on person-absent trials ($M = 75.7\%$, $SD = 11.52$) than on person-present trials ($M = 73.7\%$, $SD = 11.59$), $F(1, 138) = 6.45$, $p = 0.01$, $\eta_p^2 = 0.05$. No interaction was found between change and person presence for accuracy, $F(1, 138) = 0.59$, $p = 0.44$, $\eta_p^2 = 0.004$.

In a final step of the analysis, inverse efficiency scores (IES) were calculated. A repeated-measures ANOVA on these scores revealed no difference in efficiency for the change ($M = 6.51$ s, $SD = 4.15$) and no-change condition ($M = 6.59$ s, $SD = 3.84$), $F(1, 138) = .03$, $p = 0.86$, $\eta_p^2 = 0.00$. However, responses were less efficient for person-present ($M = 7.01$ s, $SD = 4.08$) than person-absent trials ($M = 6.08$ s, $SD = 2.49$), $F(1, 138) = 10.09$, $p = 0.002$, $\eta_p^2 = 0.07$. There was also an interaction between change and person presence, $F(1, 138) = 4.65$, $p = 0.03$, $\eta_p^2 = 0.03$. A Tukey HSD test showed that participants were less efficient for person-present change ($M = 7.29$, $SD = 7.15$) trials than person-absent ($M = 5.72$, $SD = 2.57$) change trials, $p = 0.04$, whereas these scores were more comparable for person-present and person-absent trials in the no-change condition, $p = 0.06$.

To reveal if participants were sensitive to person presence and to detecting the changes, *d'* was also calculated. A paired samples t-test revealed participants were more sensitive to no changes ($M = 3.27$, $SD = 1.06$) than changes ($M = 0.30$, $SD = 0.81$), $t(138) = 30.00$, $p < 0.001$. An additional paired samples t-test revealed participants were significantly less sensitive to changes

Table 1. A summary of the proportion of person size and location for the person-present conditions; and the proportion of change size and location in the change conditions across all three prevalence conditions for Experiment 3.

			25%	50%	75%
Person size of a proportion of total scene	Change Person-Present		1.81%	1.96%	1.91%
	No-Change-Person Present		1.79%	2.01%	1.90%
Person Placement	Change Person Present	Horizontal Middle	62.50%	65%	65.25%
		Horizontal Outer	37.50%	35%	34.75%
		Vertical Middle	95%	95%	95.50%
		Vertical Upper	2.25%	2.50%	2.25%
		Vertical Lower	2.50%	1.67%	2.25%
	No-Change Person Present	Horizontal Middle	72.50%	71.67%	71.75%
		Horizontal Outer	27.50%	28.33%	28.25%
		Vertical Middle	95%	95%	94.75%
		Vertical Upper	5%	5%	5.25%
		Vertical Lower	0%	0%	0%
Change size of a proportion of total scene	Change Person Present		2.77%	2.77%	2.77%
	Change Person Absent		2.95%	2.88%	2.95%
Change Placement	Change Person Present	Horizontal Middle	22.50%	22.50%	22.50%
		Horizontal Outer	77.50%	77.50%	77.50%
		Vertical Middle	60%	60%	59.75%
		Vertical Upper	30%	30%	30.25%
		Vertical Lower	10%	10%	10%
	Change Person Absent	Horizontal Middle	19.75%	20%	20%
		Horizontal Outer	80.25%	80%	80%
		Vertical Middle	62.50%	61.67%	65%
		Vertical Upper	27.50%	27.50%	25%
		Vertical Lower	10%	10.83%	10%

when a person was present in the scene ($M = 1.74$, $SD = 0.80$) than when absent ($M = 1.83$, $SD = 0.79$), $t(138) = 2.00$, $p = 0.05$.

Prevalence conditions

Separate 2 (change, no-change) × 2 (person present, absent) repeated-measures ANOVAs were then conducted for each prevalence level. The main effects and interactions for these ANOVAs are detailed in Table 2 and can be summarised as follows. Across all conditions, response times were faster to change than no-change trials. Additionally, responses were slower in person-present than person-absent scenes at 25% prevalence, but not at 50% or 75%.

Accuracy was consistently lower for change than no-change trials in all frequency conditions. With 50% prevalence, participants were also less accurate on person-present than person-absent trials. This effect was qualified by an interaction, whereby accuracy was lower on change trials when a person was present compared to absent, $p = 0.03$, and lower on person-present change trials compared to person-present no-change trials, $p < 0.001$.

Finally, responses were less efficient for the change than no-change condition under 75% prevalence. In

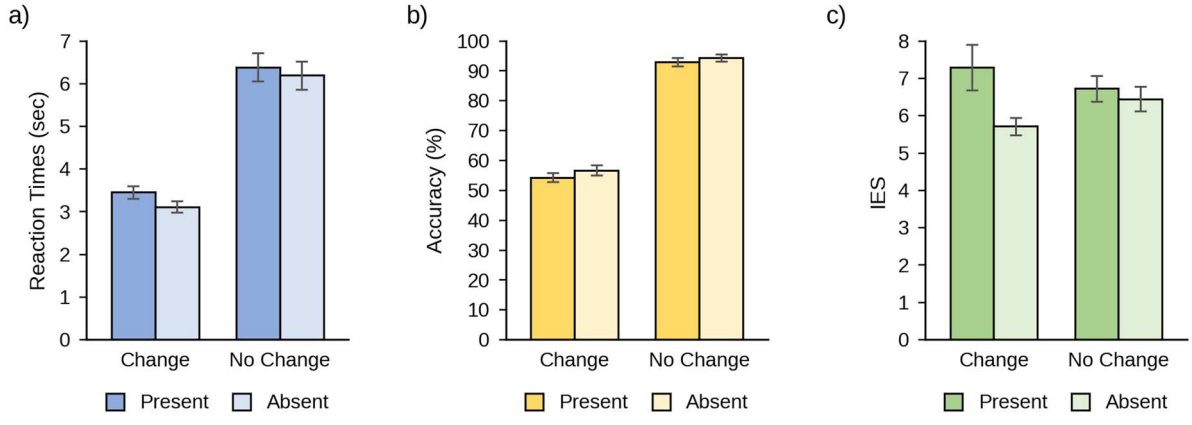


Figure 7. *Mean Reaction Times, Accuracy, and IES for Person-Present and Person-Absent Scenes in the Change and No Change conditions.*

Note: Average scores for reaction times, IES, and accuracy for person presence and person absence in the change and no change conditions. Error bars represent +/− 1 SE of the mean.

Table 2. A summary of comparisons for change and person presence, for RTs, Accuracy, IES, and *d*-prime for the 25%, 50% and 75% conditions in Experiment 3.

	Comparison		25%	50%	75%
	Change	No-Change	$F(1, 37) = 52.08$, $p < 0.001$***	$F(1, 54) = 80.73$, $p < 0.001$***	$F(1, 45) = 40.96$, $p < 0.001$***
RTs	Present	Absent	$F(1, 37) = 20.09$, $p < 0.001$***	$F(1, 54) = 3.47$, $p = 0.07$	$F(1, 45) = 0.03$, $p = 0.86$
	Change *vs*	Presence	$F(1, 37) = 2.12$, $p = 0.15$	$F(1, 54) = .12$, $p = 0.73$	$F(1, 45) = 2.24$, $p = 0.14$
	Change	No-Change	$F(1, 37) = 213.05$, $p < .001$***	$F(1, 54) = 238.61$, $p < .001$***	$F(1, 45) = 263.32$, $p < 0.001$***
Accuracy	Present	Absent	$F(1, 37) = 1.00$, $p = 0.32$	$F(1, 54) = 11.43$, $p = 0.001$***	$F(1, 45) = 0.33$, $p = 0.57$
	Change *vs*	Presence	$F(1, 37) = 1.23$, $p = 0.28$	$F(1, 54) = 4.50$, $p = 0.04$*	$F(1, 45) = 0.79$, $p = 0.38$
	Change	No-Change	$F(1, 37) = .02$, $p = .90$	$F(1, 54) = 2.04$, $p = .16$	$F(1, 45) = 11.35$, $p = 0.002$**
IES	Present	Absent	$F(1, 37) = 20.78$, $p < .001$***	$F(1, 54) = 3.86$, $p = .06$	$F(1, 45) = 0.03$, $p = 0.85$
	Change *vs*	Presence	$F(1, 37) = 5.91$, $p = .02$	$F(1, 54) = 1.73$, $p = .19$	$F(1, 45) = 0.08$, $p = 0.78$
	Change	No-Change	$t(37) = -16$, $p < 0.001$***	$t(54) = -20$, $p < 0.001$***	$t(45) = -16$, $p < 0.001$***
d prime	Present	Absent	$t(37) = 0.14$, $p = 0.90$	$t(54) = -2.90$, $p = 0.006$**	$t(45) = -1.1$, $p = 0.30$

addition, responses were less efficient for person-present than person-absent trials under 25% prevalence. No other effects reached significance.

To reveal if participants were sensitive to person presence and to detecting the changes, *d'* was also calculated. For all three conditions, A paired samples t-test revealed participants were more sensitive to no changes than changes. In the 50% condition, participants were significantly less sensitive to changes when a person was present in the scene than when absent. Yet this was not reflected in the 25% and 75% conditions.

Observers were (a) slower and (c) less efficient at responding to changes in the person-present condition in which a person was only present for 25% of trials. Consistent with Experiments 1 & 2, participants were (b) less accurate when there was a person present, appearing in 50% of trials. Person present did not have any influence when appearing in 75% of trials (Figure 8).

Discussion

Experiment 3 replicated the central finding of Experiments 1 and 2, by showing that change detection was less accurate when people were present in scenes, even though they were never relevant to the task. This effect was observed again under 50% prevalence, and extended to a new stimulus set in which all people appeared in a clear frontal view, demonstrating robustness across variations in stimuli.

Crucially, manipulating prevalence revealed an unexpected pattern. Contrary to predictions, interference emerged under low person prevalence (25%), but not under high prevalence (75%). In contrast to the 50% prevalence condition, where person presence affected accuracy, this effect was evident in response times and inverse efficiency scores when people appeared infrequently, suggesting there may have been some time-accuracy trade-off. Furthermore, differences in person presence were not reflected in *d*-prime scores for the 25% condition. This could also be attributed to a lack of power, as the person-present condition had fewer trials. This result contrasts with findings on object target frequency (Beanland et al., 2016; Biggs et al., 2014; Godwin et al., 2015; Menneer et al., 2010; Wolfe et al., 2007), which typically show stronger attentional capture for more frequent targets. One possible explanation for this finding is that under high person prevalence, it becomes apparent that changes never occur to the people in scenes, leading observers to reduce attention to them (see Bindemann et al., 2007).

General discussion

The current research suggests that people occurring in naturalistic scenes may draw attention spontaneously even when task irrelevant. Across three flicker-task experiments, change detection performance declined when a person was present, with reduced accuracy (Experiments 1–3) and, in Experiment 3, slower response times compared to person-absent scenes. This indicates that observers' attention is drawn towards people, increasing the likelihood of detection errors and prolonging search. These findings are consistent with prior evidence of attentional bias to faces (Cerf et al., 2007; Cerf et al., 2009; Crouzet et al., 2010; Langton et al., 2008; Little et al., 2021; Mayer et al., 2015; Ro et al., 2001; Simpson et al., 2014) and extend this work by showing similar effects in complex, real-world scenes.

In Experiments 1 and 2, the person-present effect was primarily found in accuracy measures, whereas Experiment 3 additionally revealed this effect in response times. Reaction time differences may be particularly difficult to detect given the time-constrained nature of the task, which requires participants to view at least one full flicker cycle prior to responding. The greater power afforded by considerably more trials and participants in Experiment 3 may have enabled response time differences to be revealed relative to the previous experiments.

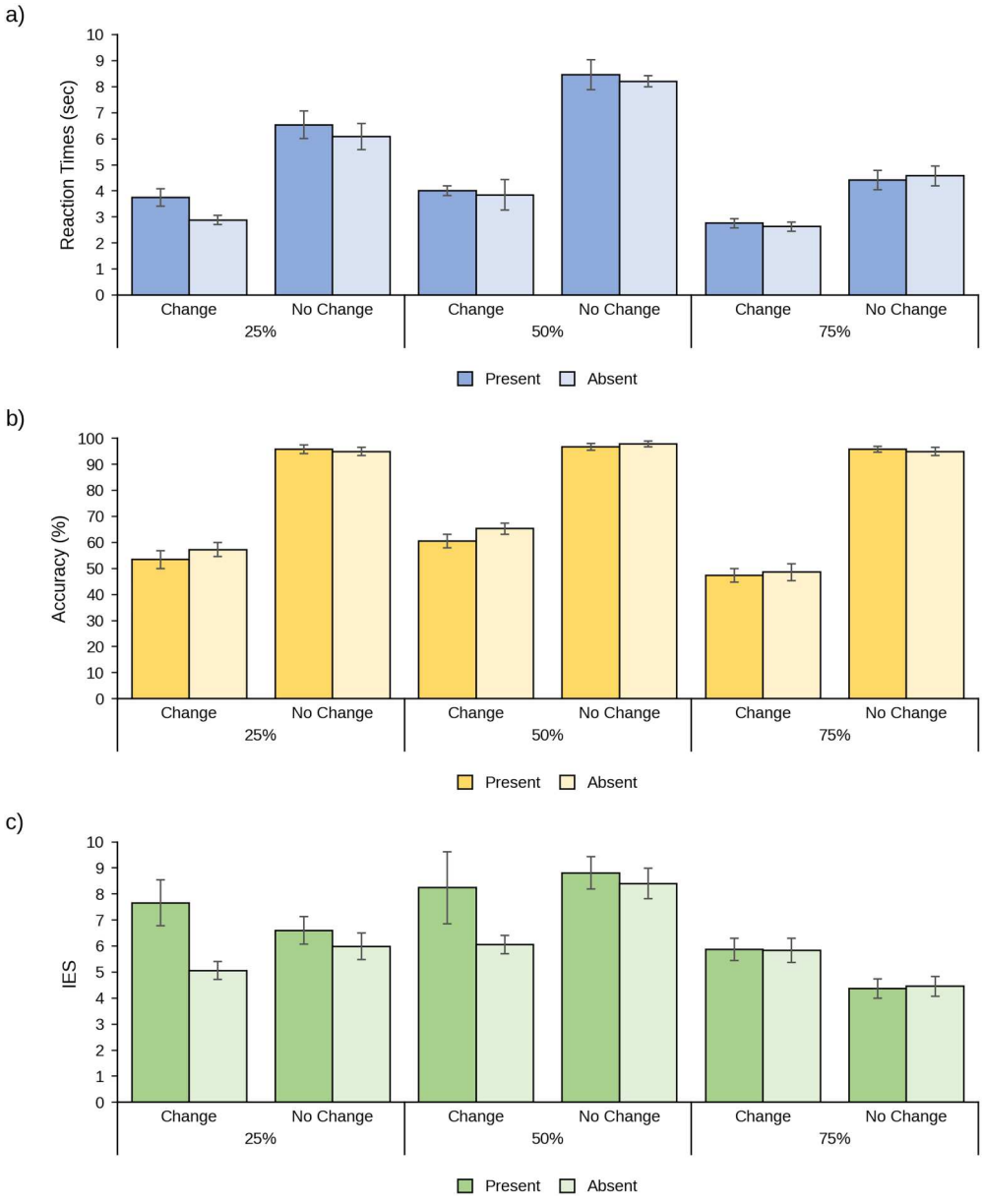


Figure 8. Mean reaction times, accuracy, and IES for person-present and person-absent scenes in the change and no change conditions at all prevalence levels.

Note: Error bars represent +/− 1 SE from the mean.

Importantly, the degree of attentional engagement depended on how frequently people appeared. In Experiment 3, person presence disrupted change detection when people appeared in 25% of trials but not when they appeared in 75%. This diverges from visual search with non-face targets, in which less frequent targets are more likely to be missed (Beanland et al., 2016; Biggs et al., 2014; Godwin et al., 2015; Menneer et al., 2010; Wolfe et al., 2007). In the current study, high prevalence may have highlighted the irrelevance of people to the change-detection task, leading observers to suppress attention to them (see Bindemann et al., 2007). However, although people were never the target of detection, their presence nevertheless seemingly drew attention with 25% and 50% prevalence, in line with previous research showing attentional biases to faces and bodies (e.g. Cerf et al., 2009; Crouzet et al., 2010; Langton et al., 2008; Little et al., 2021; Mayer et al., 2015; Ro et al., 2001; Simpson et al., 2014).

Inconsistencies in the literature on attentional capture often stem from methodological differences, such as task, cognitive load, and semantic context (Bindemann & Lewis, 2013; Hollingworth & Henderson,

2000; Nevard et al., 2023; Palermo & Rhodes, 2003). The present experiments minimise these concerns by using naturalistic photographs rather than search arrays, making the findings more representative of real-world perception. This reduces artificial "pop-out" or semantic incongruency effects (Hollingworth & Henderson, 2000; Palermo & Rhodes, 2003). Furthermore, if faces were to naturally "pop-out" as stimuli, then we would expect this effect to be consistent regardless of prevalence frequency, driven by intrinsic visual properties rather than learned frequency. As this was not observed in the 75% condition, this pattern is inconsistent with the pop-out effect, but rather indicating that social stimuli have attentional priority, even when not required for the task. This use of natural scenes indicates that this is an important distinction from prior pop-out paradigms, which have predominantly employed sparse, artificial search arrays, that may not generalise to real-world viewing (Bindemann et al., 2010; VanRullen, 2006). Natural scenes also place greater cognitive demands on visual search, making the findings more representative of real-world perception (e.g. Bindemann et al., 2010; Bindemann & Burton, 2009; Burton & Bindemann, 2009; Kelly et al., 2019). Although natural scenes introduce variability, the replication of results across two stimulus sets strengthens confidence in their robustness.

Another key contribution of this work is its focus on full-bodied figures, rather than isolated faces. In everyday vision, faces rarely appear without bodies, yet many studies of attentional bias use simplified or decontextualised stimuli. Although faces may have some attentional priority, body parts, such as arms and hands, also draw a notable amount of attention in naturalistic scenes, particularly in scenes involving action and gestures (Broda & De Haas, 2022a). Furthermore, there are individual differences in whether observers look at faces or bodies more (Broda & De Haas, 2022b). The current research demonstrates that whole people, not just faces, draw attention in scenes, consistent with research emphasising the salience of body cues (Bindemann et al., 2010; Broda & De Haas, 2022a; Fletcher-Watson et al., 2008). Presenting full-bodied figures in realistic contexts also avoids the potential artefact of faces "popping out" or appearing semantically incongruent when placed in artificial displays (Hollingworth & Henderson, 2000; Palermo & Rhodes, 2003).

In summary, these experiments suggest that people draw attention spontaneously in natural visual scenes, as evidenced by impaired change detection performance, which is consistent with previous research. However, this effect is moderated by prevalence. It is observed when people appear in half or fewer trials, but not when they appear frequently and are consistently task-irrelevant. These findings provide new insight into how attention is likely directed within scenes, indicating that while people may attract attention, this process is spontaneous rather than automatic, and can be modulated by task context.

Author contributions

Alice Nevard – Conceptualisation; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Visualisation; Roles/Writing – original draft; Writing – review & editing. Markus Bindemann – Conceptualisation; Funding acquisition; Methodology; Visualisation; Roles/Writing – original draft; Writing – review & editing. Graham Hole – Conceptualisation; Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

The data for all experiments reported in this study can be accessed at: https://osf.io/dn327/?view_only=0d425b2765894eea824d204ae254aa64.

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