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# CCTV Observation: The Effects of Event Type and Instructions on Fixation Behaviour in an Applied Change Blindness Task

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*Summary: Little is known about how observers' scanning strategies affect performance when monitoring events in closed-circuit television (CCTV) footage. We examined the fixation behaviour of change detectors and non-detectors monitoring dynamic scenes. One hundred forty-seven participants observed mock CCTV videos featuring either a mock crime or no crime. Participants were instructed to look for a crime, to look for something unusual or simply to watch the video. In both videos, two of the people depicted switched locations. Eye movements (the number of fixations on the targets and the average length of each fixation on targets) were recorded prior to and during the critical change period. Change detection (24% overall) was unaffected by event type or task instruction. Fixation behaviour differed significantly between the criminal and non-criminal event conditions. There was no effect of instructions on fixation behaviour. Change detectors fixated for longer on the target directly before the change than did non-detectors. Although fixation behaviour before change predicted change detection, fixation count and durations during the critical change period did not. These results highlight the potential value of studying fixation behaviour for understanding change blindness during complex, cognitively demanding tasks (e.g. CCTV surveillance). Copyright © 2017 John Wiley & Sons, Ltd.*

Although closed-circuit television (CCTV) footage is used in both crime prevention and police investigations to prosecute criminals, relatively little is known about the strategies that observers use when monitoring and interpreting (criminal) events observed in such footage. Howard, Troscianko, Gilchrist, Behera, and Hogg (2009) stated that measuring eye movements during CCTV monitoring might produce innovative data to determine the strategies people use when attending to footage. Stainer, Scott-Brown, and Tatler (2013) examined the eye movements of two trained CCTV operators monitoring multiple display screens on a wall, compared to a single-spot monitor (the operator could select only one of multiple screens to inspect in more detail). They found that more attention was allocated to the single-screen-spot monitor than the multiplex display, with the more (cf. less) experienced operator utilising the spot monitor more often. Stainer et al. (2013) identified that their observers selectively allocated attention based on expected informativeness. This replicated Howard, Troscianko, and Gilchrist's (2010) finding that participants with more experience watching football matches shifted their eyes to more informative areas of the footage earlier than did non-experienced observers. Following on from this work, we investigated whether event type and instructions affected fixation behaviour during CCTV observation and whether fixation behaviour predicted observers' detection of critical changes in the footage.

## Effects of task instructions on eye movements

The notion that task instructions guide attention in visual scenes has been extensively researched, beginning with Yarbus's (1967) classic experiments. Eye movements are influenced by task and goals, and where individuals fixate on a scene varies according to viewing instructions given prior to the task (Mills, Hollingworth, Van der Stigchel, Hoffman, & Dodd, 2011). Real-world eye movement studies show similar results, with participants fixating more on task-relevant objects than even the most visually salient objects (Land & Hayhoe, 2001; Tatler & Tatler, 2013). Furthermore, instructing participants to search for an object or to memorise a scene influences fixation locations (Castelhano, Mack, & Henderson, 2009; Henderson, Weeks, & Hollingworth, 1999). In terms of dynamic real-world visual search, Howard, Gilchrist, Troscianko, Behera, and Hogg (2011) found that task relevance determined where observers attended whilst watching CCTV footage, with participants fixating more often on suspicious behaviour after being instructed to do so. Thus, task instructions have a significant influence on eye movements during scene viewing. However, Castelhano et al. stressed the difficulty of establishing a clear theory or model of fixation durations in scene perception (compared to reading, e.g. Reichle, Rayner, & Pollatsek, 2003) as the task and stimuli are often varied. Furthermore, the majority of current models are based on static scene or picture viewing paradigms, making it difficult to generalise these models to broader contexts such as interpreting dynamic stimuli (Tatler, Hayhoe, Land, & Ballard, 2011).

With these limitations in mind, we aimed to develop our understanding of how individuals visually attend to dynamic scenes by investigating the effects of task instructions on visual attention and change blindness during CCTV observation. Previous research has found that task instructions influenced the detection of changes in dynamic scenes. For example, when viewing a video of a staged burglary, people told to remember content from the video noticed a change in the burglar's identity more often than people given no specific instruction (Davies & Hine, 2007). However, although instructions can improve change detection, they do not

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eliminate change blindness. In Levin and Simons' (1997) classic change blindness study, even participants explicitly instructed to look for changes noticed only two of the nine changes presented. This idea of prioritising visual attention based on task goals is known as attentional set (e.g. Most, Scholl, Clifford, & Simons, 2005).

Therefore, previous research highlights that participants allocate their attention to scenes systematically based on task goals and instructions (i.e. attending to areas of suspicious behaviour on CCTV footage when instructed to detect criminal behaviour). We wanted to test if the same will occur during CCTV observation by using an applied change detection task. This will inform how much providing instructions or any prior information before CCTV observation affects how people visually attend to the footage.

Given that task instructions influence where individuals attend to in a scene (Howard et al., 2011), we predicted that our observers would fixate on task-relevant aspects of the footage (i.e. those instructed to detect a crime would focus on features of the footage related to the crime). In the present study, two of the actors in both the crime and no-crime videos switched locations. The criminal event (stealing a phone) in the crime video took place directly after the switching of the two actors (i.e. the 'critical change period'). We predicted that participants instructed to 'detect a crime' would show more and longer fixations on the targets, before and during the critical change period, than those instructed to 'detect anything unusual' or given no instruction and that this would facilitate change detection.

### Effects of event type on eye movements

Although eye-tracking studies have investigated how individuals attend to static scenes (e.g. Castelhano et al., 2009), few studies have investigated how individuals attend to dynamic stimuli. Therefore, we aimed to develop an understanding of fixation behaviour during the observation of dynamic CCTV footage. Related to fixation behaviour, the rationale for looking at both fixation durations and counts in the present study was to investigate whether the number of fixations (i.e. relatively rapid scanning) or length of fixations (i.e. more careful scanning) facilitates change detection.

There are parallels between the visual strategies applied to events in CCTV footage and perceptual research investigating how individuals observe and understand films. Information in both CCTV footage and film footage is generally formed of several camera angles and cuts. Therefore, it makes sense that the researchers looking at the perceptual and cognitive understanding of films are applying findings from the eye tracking of dynamic scenes (Smith, Levin, & Cutting, 2012). For instance, Mital, Smith, Hill, and Henderson (2011) found that observers attend to areas of high motion in a dynamic scene. These findings can be applied to CCTV observation, which features different amounts of motion in the footage. On the one hand, there may be footage with very little taking place compared to a busy city centre CCTV camera stream. In line with Mital et al.'s (2011) findings, presenting both criminal and non-criminal events within CCTV footage may further our understanding of how we attend to different areas of motion within the footage.

Furthermore, Hirose, Kennedy, and Tatler (2010) investigated participants' recognition memory and eye movement patterns whilst observing short video clips involving a viewpoint change (a cut). During the cut, an object's shape, colour, identity or position was manipulated. Hirose et al. found that memory for object location in a scene was significantly worse than memory for object identity or colour. During the observation of CCTV footage, there is often a cut to another camera stream. Therefore, memory for location in CCTV footage may be hindered in a similar way to Hirose et al.'s participants. This may have implications if features in the CCTV footage were misidentified between cuts in the camera angle. For example, in a busy CCTV scene, there are a large number of people and objects competing for attention. A CCTV operator may focus on someone with a suitcase sitting on a bench. The camera might then cut to another steam. The camera then returns to the man sitting with the suitcase. However, the CCTV operator is unaware that the suitcase has been switched with another, more suspicious suitcase. The reason that the operator is not aware of this is due to the same type of object being spatially in the same place. This might also be the case for people, presenting implications in terms of misidentification in a forensic context (e.g. Levin & Simons, 1997). We will investigate whether observers can detect changes to personnel in a video, when these changes occur during a cut.

Combining how we perceptually understand films with our interpretation of real-world dynamic scenes may further our understanding of how we understand events in CCTV footage. No research to date has directly compared eye movements for criminal and non-criminal events. We included both criminal and non-criminal events for two reasons. First, real-world CCTV footage features both criminal and non-criminal events. Second, observers may rely on cues from footage to help them understand what is happening concurrent with any expectations they have about what constitutes suspicious behaviour. No specific hypotheses were made; however, we wanted to investigate how event type impacts fixations behaviour and whether either of these events predicts change detection behaviour.

### Change blindness

Observing CCTV footage can place a considerable demand on the visual system, yet almost all of our visual processing seems effortless and automatic (Scott-Brown & Cronin, 2007). This overarching feeling of visual 'completeness' can lead to an overestimation of our visual abilities, and psychological research demonstrates that our perceptual systems can fail to detect changes in the environment (Scott-Brown & Cronin, 2007). For example, inattentional blindness refers to observers failing to detect an unexpected object in their visual field, usually whilst attention is directed towards another task or object (Mack & Rock, 1998). One of the classic lab-based studies of inattentional blindness by Simons and Chabris (1999) involved participants watching two different teams passing a basketball to each other. Participants were asked to count the number of passes made between team members wearing white t-shirts and team members wearing black t-shirts. In the video, a person wearing a gorilla suit walked through the scene. Approximately half of the participants failed to notice the gorilla in the scene. Nasholm, Rohlfing, and Sauer (2014) applied an inattentional blindness task during CCTV monitoring to investigate the effects of top-down processing on detection rates. They found that 66% of participants failed to detect the unexpected stimulus in the CCTV footage. Therefore, examining the eye movements of participants watching CCTV stimuli may inform us about the strategies that are in play, concluding in either successful or unsuccessful detection behaviour.

Change blindness, a similar phenomenon, refers to an inability to detect changes in our perceptual environment from one view to the next (Levin & Simons, 1997). Early research demonstrated that observers can fail to detect even large changes to pictures of objects or real-world photographs (e.g. Blackmore, Brelstaff, Nelson, & Troscianko, 1995; Grimes & McConkie, 1995), concluding that an eye movement or flashed blank screen may increase difficulty in detecting changes to the visual details of a scene (see Rensink, O'Regan, & Clark, 1997, for an example of the flicker paradigm). The level of change blindness in visual perception suggests restrictions on our capacity to encode, retain and compare visual information from one glance to the next (Simons & Ambinder, 2005). This is due to the stable nature in which we believe we are interpreting our visual environment and an overestimation of how much of it we are attending to (Simons & Levin, 1998).

Observers can even miss a change in the identity of an actor between a cut in camera angles (Levin & Simons, 1997). Astonishingly, observers also miss changes during real-world interactions (Simons & Levin, 1998). Change blindness can also have important applied implications for security settings. For example, failures to detect change (e.g. a switch between two people as a crime takes place) when monitoring CCTV footage in forensic contexts have serious consequences (e.g. the pursuit or arrest of an innocent person).

Little research has investigated variations in the visual strategies of change detectors and non-detectors. Considering the aim of change blindness studies is generally to test perceptual limitations when attending to scenes (Simons & Rensink, 2005), it would be beneficial to develop an understanding of real-time fixation behaviours leading up to and during change blindness. Identifying specific visual strategies associated with change detection (or change blindness) may help influence guidance regarding how individuals should attend to dynamic, constantly changing stimuli.

Previous CCTV studies have demonstrated that observers use specific cues from CCTV footage (i.e. body position and gesture) to determine if criminal behaviour is about to take place (Troscianko et al., 2004). This information is attended to directly before the criminal event takes place in the footage. Other research has used eye movements as a predictive behaviour. For example, in a sporting context, Savelsbergh, Williams, Van der Kamp, and Ward (2002) found that expert football players demonstrated accuracy at predicting the height and direction of penalty kicks. Furthermore, they exhibited longer fixation durations on the opponent's non-kicking leg prior to the penalty kick. The eye movements *before* the action provided an insight into the strategies adopted by this expert group. A real-world eye tracking study by Pelz and Canosa (2001) found that participants sometimes produced *look-ahead fixations*, which were related to future actions associated with the task (e.g. looking at a kettle before picking it up to pour water into a cup). Therefore, we investigated whether we could apply the notion of look-ahead fixations (Pelz & Canosa, 2001) to a dynamic, observational task where anticipatory eye movements may fall on people associated with the task goal (e.g. fixating for longer on suspicious people before the crime is committed). We expected that successful change detection would occur if participants fixated on the target directly before the change took place. Furthermore, instructions might guide attention to certain aspects of the scene, increasing the chances that participants are looking at the target prior to the change and consequently increasing the likelihood of change detection. Finally, we investigated whether differences in fixation behaviour predicted change detection when monitoring CCTV footage.

## PILOT STUDY

A pilot study established that participants were able to identify that one video depicted a crime and the other did not. We also established that some observers were able to identify the critical in the videos in order to avoid a floor effect for change detection and that our targets looked suitably 'suspicious'.

### Participants

Forty undergraduate students participated (29 women and 11 men). Participant ages ranged from 18 to 46 years ($M$ = 24.50 years, $SD$ = 7.45 years).

### Materials

Mock CCTV footage was filmed using two JVC Everio digital cameras (model number GZMG750BEK), and the footage was edited using Adobe Premier Pro. The two black-and-white CCTV videos created after editing were identical except for a 5-second segment. In that segment, one video showed a crime taking place and the other showed the continuation of non-criminal behaviour. The videos showed six people entering, sitting and leaving the room of a doctors' surgery. Each video was 2 minutes long and alternated every 5 seconds between two different camera viewpoints showing different parts of the doctors' waiting room (Figure 1). Motivation for the alternating camera viewpoints was twofold. First, it allowed for change blindness to take place between a cut in camera angle, a methodology used successfully in previous change blindness research (Levin & Simons, 1997). Second, it approximates real-life CCTV footage.

In the crime video, a male stole a phone that was left on one of the chairs by a female. In the no-crime video, the female returned to collect the phone from the chair (Figure 2).

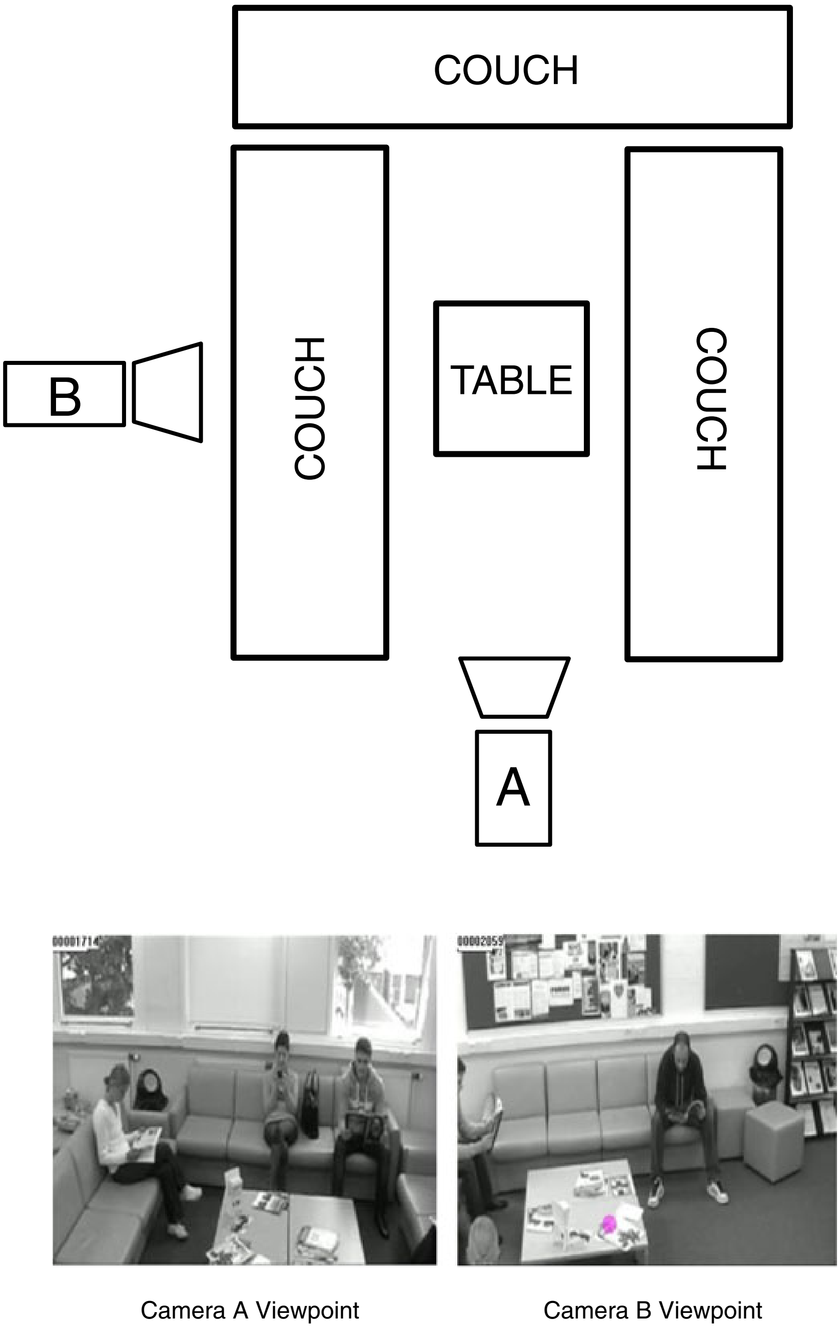



Figure 1. Plan view diagram (adapted from Smith, 2010) indicating the position of the cameras. [Colour figure can be viewed at wileyonlinelibrary.com]

After the 1:25 minute mark, following a switch in the camera perspective, the two target actors changed position (Figure 2). The change occurred immediately prior to the phone being stolen (crime video) or the owner returning to retrieve their phone (non-crime video).

### Procedure

Observers watched one of the two mock CCTV videos. Both videos were uploaded to an online survey site (https://www.psychsurveys.org), allowing participants to complete the study off-campus. After viewing the footage, participants answered the following questions about the videos:

1. Is there a criminal event taking place in the video (if yes, please describe it)?
2. Did you notice any changes in the video (if yes, describe them)?
3. Was anyone acting suspiciously in the video? (if yes, who?)
4. Any general comments?

### Results

The videos were regarded suitable for the main experiment because all observers in the crime event condition, and no observers in the no-crime condition, identified that a crime took place. Moreover, 40% of the pilot participants spotted the change in the identity of the male target in either the crime or no-crime video. Seventy per cent of participants reported that the male targets ‘looked suspicious’.


Figure 2. An illustration of the key sequence in the 2-minute video showing the two different camera viewpoints, the change and the crime and no-crime experimental conditions (adapted from Hirose et al., 2010). The criminal event shows the male picking up the phone that has been left by the lady exiting the seated area. The male proceeds to place the phone in his pocket. In the no-crime event, the lady returns to collect her phone after realising she has dropped it. No crime is committed. The purple dots represent an example of the position of an observer's eye movement. [Colour figure can be viewed at wileyonlinelibrary.com]

## MAIN STUDY

### Participants

One hundred forty-seven participants took part in the experiment (91 women and 56 men). Participants ages ranged from 18 to 50 years ($M$ = 29.62 years, $SD$ = 6.91 years). All participants had normal or corrected-to-normal vision.

### Design

Event type (crime or no crime) and instruction (detect crime, detect anything unusual or no instruction) were manipulated between subjects. The dependent measures were two measures of eye movements: fixation count (the number of fixations on the targets) and fixation duration (average time of each fixation on targets measured in milliseconds), prior to and during the critical change period.

Change detection was recorded, for each condition, as the percentage of the participants who correctly detected the change. In subsequent analyses, change detection was used as an outcome variable to see whether change detection could be a predictor based on changes in eye movement behaviour. For the remainder of the paper, the two actors who switched during the videos will be referred to as 'Target 1' and 'Target 2' (Figure 3).

### Materials

The videos (described for the pilot study) were presented on a computer monitor. Experiment Builder software (SR Research, Ltd, Osgoode, Canada) was used to programme the experiment. A second computer, used to control the eye tracker, was linked to the computer presenting the videos. The video-based EyeLink 1000 (SR Research, Ltd) was used to record participants' eye movements and was run at 1000 Hz whilst tracking both pupil and corneal reflection. A chin-rest was used to maintain the participants' viewing position of 50 cm from the computer monitor.

### Procedure

After informed consent was obtained, the eye tracker measurements were calibrated using a 9-point grid. Calibration was repeated, if necessary, until predicted and actual fixation positions differed by no more than 0.5°. Participants were randomly allocated to one of the six experimental conditions. The relevant instruction (detect crime, detect anything unusual or no instruction) appeared on the screen before the video played. Participants were given as much time as they needed to read the instruction before clarifying to the experimenter that they understood and were happy to proceed.


Target 1 Target 2

Figure 3. The two male targets. Target 2 took the place of Target 1. [Colour figure can be viewed at wileyonlinelibrary.com]

Participants then watched a video clip. Eye tracking was stopped once the video finished.

After the experiment, participants completed a questionnaire measuring recall from the footage and change detection. Participants were asked ‘Did you detect any change in the video?’ and were asked to respond yes or no. If participants stated that they detected a change, they were asked to describe the change using a free text box. Participants were given as much time as required for answering the questions and were then debriefed. The experiment lasted approximately 20 minutes.

## Data

Fixation durations were only included if they were 100 milliseconds long or longer. Raw eye movement data were analysed using the DataViewer (SR Research, Ltd) software. The 2-minute videos were edited down to two key stages for analysis; the 5 seconds immediately *before the critical change period* and the 10-second *critical change period* in which the two men each appeared for the first time in their new positions (Figure 4). Fixation count and fixation duration served as the dependent variables, with these parameters representing the number of times the targets were fixated on and for how long.

## Results

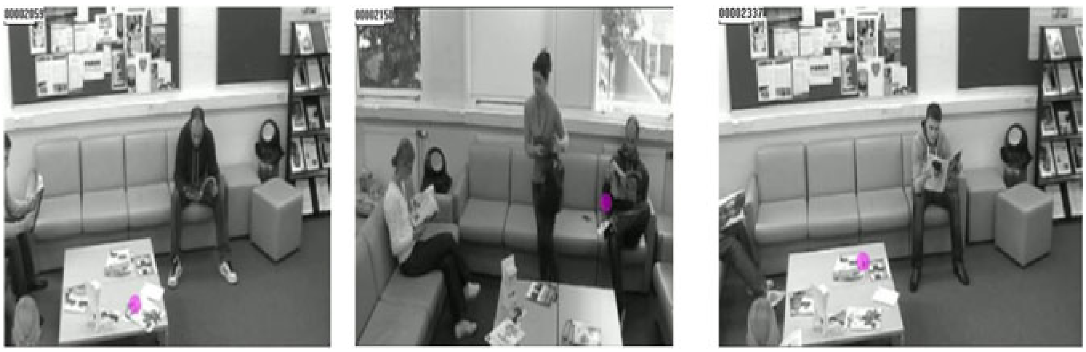
### *Eye movements*

To address our first research question—do task instructions and event type affect fixation behaviour—we ran a series of analyses relating to the ‘before change’ period and the ‘critical change’ period.

*Before change.* A multivariate analysis of variance (MANOVA) was conducted with instruction (detect crime, detect anything unusual or simply watch the video) and event type (crime or no crime) as the independent variables and number of fixations on targets (fixation count) and average fixation duration in the 5 seconds before the critical change as the dependent variables.

The MANOVA revealed no significant multivariate main effect of instruction, Wilks’s $\lambda$ = .991, $F(1, 147) = 0.30$, $p = .875$, partial $\eta^2 = .004$. Therefore, contrary to our expectation, instructions did not affect fixation behaviour before the critical change period.

The MANOVA revealed a significant multivariate main effect for event type, Wilks’s $\lambda$ = .949, $F(2, 140) = 3.74$, $p = .026$, partial $\eta^2 = .051$. A follow-up univariate analyses revealed a significant main effect of event type on fixation count, $F(1, 147) = 5.48$, $p = .021$, partial $\eta^2 = .087$, with



1. Before change (5 seconds) 2. Change period, Target 1 (5 secs) 3. Change period, Target 2 (5 secs)

Figure 4. Stills taken from the closed-circuit television footage depicting the two key stages where eye movement behaviour of our observers was examined. Still 1 portrays the 5 seconds immediately before the change occurs. Stills 2 and 3 represent the critical change period. Still 2 is the first 5 seconds of the change period featuring Target 1, and Still 3 is the last 5 seconds of the change period featuring Target 2. [Colour figure can be viewed at wileyonlinelibrary.com]

fewer fixations being made when participants were viewing the crime video ($M$ = 4.78, $SD$ = 2.15, 95% CI [4.31, 5.30]) compared to the no-crime video ($M$ = 5.68, $SD$ = 2.46, 95% CI [5.12, 6.27]). However, there was near significance related to longer fixation durations, $F(1, 147) = 3.77$, $p = .054$, partial $\eta^2 = .026$, made by the participants watching the crime video ($M$ = 450.51 milliseconds, $SD$ = 467.41, 95% CI [353.77, 571.42]) compared to those watching the no-crime video ($M$ = 337.46 milliseconds, $SD$ = 170.16, 95% CI [301.32, 376.53]). Thus, participants watching the crime video produced fewer fixations on the target, but there is a hint that this was offset by these participants producing longer fixations on the target.

*Critical change period.* The switch in location of the two targets took place over two scenes; therefore, the critical change period analyses were split by target (Target 1 from Scene 1 and Target 2 from Scene 2; Figure 5). For each target, we ran a MANOVA to test whether event type and instruction affected fixation behaviour.

*Target 1.* The MANOVA revealed no significant multivariate main effect of instruction, Wilks's $\lambda = .958$, $F(2, 140) = 1.52$, $p = .196$, partial $\eta^2 = .021$. Therefore, no support was found for the prediction that participants instructed to detect a crime would show more and longer fixations on the target during the critical change than those instructed to detect anything unusual or those given no instruction.

The MANOVA revealed a significant multivariate main effect for event type, Wilks's $\lambda = .646$, $F(1, 147) = 38.40$, $p < .001$, $\eta^2 = .354$. Therefore, observers watching the crime video would produce more and longer fixations on Target 1 during the change than those watching the no-crime video. A significant univariate main effect was obtained for event type on fixation count, $F(1, 147) = 77.28$, $p < .001$, partial $\eta^2 = .354$, with more fixations on Target 1 made when participants were viewing the crime video ($M$ = 5.96, $SD$ = 2.32, 95% CI [5.43, 6.48]) compared to the no-crime video ($M$ = 2.93, $SD$ = 1.94, 95% CI [2.42, 3.34]). There was no significant main effect of event type on fixation duration, $F(1, 147) = 0.04$, $p = .842$, partial $\eta^2 = .000$. In line with our expectation, participants watching the crime video produced more fixations overall compared to those watching the no-crime video.

The MANOVA revealed no significant interaction between event type and instructions, Wilks's $\lambda = .959$, $F(4, 140) = 1.49$, $p = .205$, partial $\eta^2 = .021$.

*Target 2.* The MANOVA revealed no significant multivariate main effect of instruction, Wilks's $\lambda = .959$, $F(4, 280) = 1.48$, $p = .209$, partial $\eta^2 = .021$. Therefore, contrary to our expectation, instructions did not affect fixation behaviour.

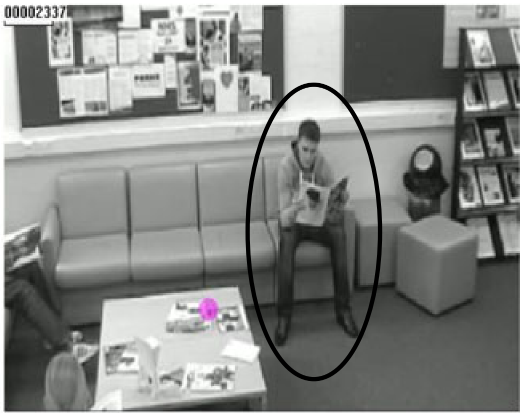
The MANOVA revealed a significant multivariate main effect for event type, Wilks's $\lambda = .733$, $F(2, 140) = 25.48$, $p < .001$, $\eta^2 = .267$. A significant univariate main effect was obtained for event type on fixation count, $F(1, 147) = 29.66$, $p < .001$, $\eta^2 = .174$, with more fixations made when participants were viewing the crime video ($M$ = 7.18, $SD$ = 2.66, 95% CI [6.58, 7.75]) compared to the no-crime video ($M$ = 5.07, $SD$ = 2.11, 95% CI [4.56, 5.54]). There was no significant main effect of event type on fixation duration, $F(1, 147) = 3.16$, $p = .078$, $\eta^2 = .022$. As with Target 1 and consistent with our expectation, participants watching the crime video produced more fixations overall compared to those watching the no-crime video.

The MANOVA revealed no significant interaction effects of event type and instructions, Wilks's $\lambda = .967$, $F(4, 140) = 1.91$, $p = .315$, partial $\eta^2 = .017$.

*Change detection*

Of the 147 participants tested, only 36 detected the change (24.5%, Table 1). Chi-square tests were performed to see if event type or instruction was associated with change detection. There was no relationship between event type and change detection, $\chi^2(2, N = 147) = 0.185$, $p = .705$, or between instructions and change detection, $\chi^2(2, N = 147) = 0.519$, $p = .787$.


(a)




(b)

Figure 5. (a) Target 1. At this point in the video, Target 1 has switched from his original position. This is the very first point in which our observers may identify that the change has taken place. Target 1 remains on screen for 5 seconds during the critical change period. (b) Target 2. This is the first time observers see target 2 in his new position after switching with target 1. Target 2 remains on the screen for 5 seconds. The critical change period lasts 10 seconds, which gave our participants time to see both of our targets after they had switched positions. The analysis considers Targets 1 and 2 separately. [Colour figure can be viewed at wileyonlinelibrary.com]

Table 1. Number of change detectors as a function of event and instruction type

| Change detected | Event type | Instruction type: Detect crime | Detect anything unusual | No instruction | Overall |
|---|---|---|---|---|---|
| Non-detectors | Crime | 20 | 19 | 18 | 57 |
| | No crime | 16 | 18 | 20 | 54 |
| | Overall | 36 | 37 | 38 | |
| Detectors | Crime | 5 | 6 | 6 | 17 |
| | No crime | 8 | 7 | 4 | 19 |
| | Overall | 13 | 13 | 10 | |

Although no specific hypotheses were made, logistic regression analyses were calculated to ascertain whether fixation count and fixation duration (i) immediately before the change took place, (ii) during the critical change period with reference to Target 1 and (iii) during the critical change period with reference to Target 2 were predictors of change detection.

*Before the change period.* The logistic regression analysis was statistically significantly, $\chi^2(1, N = 147) = 5.729$, $p = .017$. The Wald criterion demonstrated that only fixation duration made a significant contribution to change detection prediction ($p = .040$). Fixation count was not a significant predictor of change detector ($p = .059$). Therefore, the amount of time spent fixated on the target prior to the onset of the change was a predictor of change detection.

*During the critical change period.* For Target 1, the logistic regression analysis was non-significant, $\chi^2(2, N = 147) = 2.162$, $p = .339$. The Wald criterion demonstrated that both fixation count ($p = .742$) and fixation duration ($p = .201$) were not successful predictors of change detection.

Similar results were found for Target 2, $\chi^2(2, N = 147) = 0.055$, $p = .973$. The Wald criterion demonstrated that both fixation count ($p = .964$) and fixation duration ($p = .840$) were not successful predictors of change detection. Thus, eye movement behaviour during the critical change period did not predict change detection.

## DISCUSSION

We examined the fixation behaviour of participants, who were given varying instructions, watching CCTV footage that depicted either a criminal or non-criminal event. A change detection paradigm was included, involving the switching of location of two male targets during a cut in camera angle. Specifically, we were interested in three main issues. First, we examined whether task instructions influenced how people attended to a dynamic scene with a large array of factors competing for attention. Second, we examined whether the nature of the event being viewed (criminal versus non-criminal) would influence where people attended. Third, we examined whether differences in fixation behaviour could differentiate between those who detected a change (change detectors) and those who experienced change blindness (non-change detectors). One striking finding was that all of our significant results related to the CCTV footage depicting a criminal event. No differences in eye movement behaviour were found for participants watching the no-crime video.

### Instructions and eye movements

Instructing participants to detect a crime, detect anything unusual or simply watch the footage produced no significant effect on eye movement behaviour immediately before the change took place, nor during the critical change period. This result was initially surprising. Previous research has found that task instructions influence observers' visual attention (Howard et al., 2011) and that observers can use cues in CCTV footage to predict criminal behaviour (Troscianko et al., 2004). Thus, we expected our observers would fixate on task-relevant aspects of the footage (i.e. those instructed to detect a crime would focus on features of the footage depicting potentially suspicious behaviour: our targets).

Previous research using static, picture-based paradigms found that instructing participants to search for an object or to memorise a scene influenced the locations they fixated on (Castelhano et al., 2009; Henderson et al., 1999). However, unlike static images, where the context is stable during observation, viewing dynamic scenes involves constant updating and changing of the visual information available. The variability associated with this complex, noisy visual environment might attenuate effects of instructions on fixation behaviour. At any rate, our results are consistent with Howard et al.'s (2009, p. 5) conclusion that 'the visual complexity of CCTV images, and their dynamic nature are likely to influence performance in a manner that is very different from the static, simple stimuli used in the laboratory'.

### Event type and eye movements

In terms of the effect of event type (crime versus no-crime) on eye movements, one finding stood out regarding the different fixation patterns immediately before the change took place and during the critical change period. Immediately before the change took place, participants watching the crime video produced fewer fixations on the target, but there is a hint that this was offset by these participants producing longer fixations on the target compared to those watching the no-crime video. In contrast, during the first part of the critical change period, there were more fixations on Target 1 from participants watching the crime video compared to those watching the no-crime video; however, there was no effect of event type on fixation durations. One explanation for this is that the switching of targets took place at exactly the same time as the crime. The large number of fixations on the target during the crime could be the result of an increase in the complexity of the footage and the need to try to understand the unfolding criminal event. Therefore, more fixations were necessary to process the visual information (Birmingham, Bischof, & Kingstone, 2008).

To further examine the role of fixation behaviour during CCTV observation, similar tests with expert CCTV operators should be undertaken to establish if they perform more accurately and in a similar way to our change detectors. Previous research has shown that experts in particular fields such as driving (Land & Tatler, 2001; Underwood, Chapman, Brocklehurst, Underwood, & Crundall, 2003), cricket (Land & McLeod, 2000) and radiography (Donovan & Litchfield, 2013; Litchfield & Donovan, 2016) show significantly different eye movements to novices. Therefore, future research should establish whether there is an expertise effect when observing events depicted via CCTV footage.

The findings from this study suggest that attention is drawn towards criminal events, as fixation behaviour differed significantly between the criminal and non-criminal event conditions. Participants may have fixated on the target (the offender) in this study in anticipation of something taking place and then continued focusing as the crime was committed. One way to explore this further would be to have busier CCTV scenes with a number of events taking place in the footage. Future research should test attention to changes both centrally and in the periphery of CCTV footage.

### Change detection

In line with previous change blindness research (Levin & Simons, 1997; O'Regan, Deubel, Clark, & Rensink, 2000), a large number of participants in the current study failed to detect the change in the videos. Additionally, change detection rates were unaffected by instruction and event type.

The amount of time spent fixated on the target prior to the onset of the change was a predictor of change detection. In contrast, eye movement behaviour during the critical change period did not predict change detection. There are two important points to make regarding the change detection results. First, one of our most interesting findings is the idea that eye movements before a change occurred may be a useful predictor of whether observers will detect a change. Our regression analyses illustrated a significant effect of fixation duration on change detection: longer fixation durations before the change period were positively associated with change detection. This coincides nicely with our argument earlier that our participants fixated 'ahead' on our target in an anticipatory fashion, which in turn led to successful change detection. It also supports previous research that has found that anticipatory eye movements may fall on people (rather than objects) associated with the task goal (Pelz & Canosa, 2001; Savelsberg et al., 2002).

Second, for both the criminal and non-criminal events, the CCTV footage leading up to the change was exactly the same. So why was there a difference in fixation duration behaviour between those randomly assigned to watch the criminal event and those watching the non-criminal event before any difference had occurred in the footage? There was no significant effect of instructions on fixation duration before the change, so it may be solely down to the observers understanding of the footage unfolding in front of them.

In summary, participants' fixation behaviour directly *before* the change took place predicted change detection. However, this was only the case when the event depicted in the CCTV footage was of a criminal nature. Fixation behaviour *during* the critical change period did not predict success in terms of change detection.

## CONCLUSION

The present study is the first to investigate fixation behaviour of change detectors and non-detectors for dynamic scenes. Task instructions did not affect fixation behaviour, but event type did. Perhaps more importantly, fixation behaviour before a change occurred may be a useful predictor of whether observers will detect that change, with evidence of longer fixations on the target *prior* to the change predicting change detection. However, fixation count and durations *during* the critical change period did not predict change detection. This is consistent with participants fixating ahead on the target in an anticipatory fashion, which in turn led to successful change detection. The findings highlight (a) the complexity of understanding the perceptual and attentional processes involved in the observation of complex, dynamic displays and (b) potential limitations of generalising conclusions based on static displays to dynamic visual environments.

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